# Concrete

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## For Better Concrete

Our growth of knowledge about concrete comes generally speaking, from two sources—(1) from the technical man, working in the laboratory or as a designer, and (2) from the man on the job who actually manipulates the materials.

Anything which the technical man advances as a theory of better practice, from research, tests, computations, is merely interesting in an academic way until the idea is translated to workable procedure on the job.

It is therefore of special interest and importance that such an organization as the American Concrete Institute is building its whole program of activity more and more in recognition of the necessity of getting the technical man and the practical man onto a common ground of understanding.

Never before perhaps—certainly not in recent years, has a concrete convention program seemed to promise more of practical appeal than the preliminary program just announced for the 19th Annual Convention of the American Concrete Institute to be held at Cincinnati, January 22, 23, 24, 25. It is given in some detail in other pages of this issue.

## Concrete Pavements in 1922

The past construction year—with all of its troubles in the form of bad weather, railroad strikes and consequent material shortages—has seen another big advance in the amount of new concrete pavement placed at the service of the American people. Nearly 62 million square yards have been completed and opened to traffic according to Portland Cement Association tabulations. More than two-thirds of this amount was placed on the highways—the equivalent of 4200 miles of road 18 feet wide. Over 17 and a quarter million square yards were laid in cities for street and alley pavement.

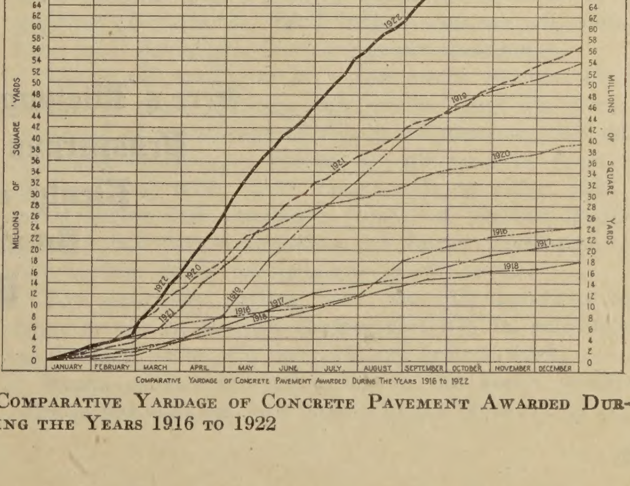
Back at the beginning of the year, there were 22,600,000 square yards of concrete pavement under contract and uncompleted—hold over work from the 1921 season. That year was almost ideal from the contractor's standpoint—a long season of good construction weather, no railway troubles to speak of, and plenty of labor. The amount undone at the end of the year was relatively small.

Generally, conditions have not been so favorable during 1922. In many states, spring rains continued in such volume into May, and even June, that active work could not be started.

Good weather prevailed generally during the summer; but about August 15 the effect of the coal strike, and the railway shopmen's strike, began to be felt to such an extent as to shut off the supply of materials. The cement plants could not get coal—they must have 50 pounds of coal to make a sack of cement—the railroads could not haul sand and stone because of their own coal shortage and because of bad equipment. In some states, contractors could not even obtain the small amount of coal required for the boilers on the concrete mixers. Later, when the coal and railway labor trouble was adjusted, and production and transportation could be resumed, the food crops had to be moved, and vast quantities of coal hauled to build up winter reserves near the points of consumption.

Taking all of these delays into consideration, it seems reasonable to estimate the 1922 working season at not more than four and one-half months. The previous year offered a working season of nearly seven months. As the total production of concrete pavement in 1921 was only slightly larger than in 1922, it seems evident that the contractors of the country have increased their capacity this year. In other words, concrete pavement production in 1921 was at the rate of about 8½ million square yards per month, while this year it has been at the rate of 13¾ million square yards every month. This is equivalent to more than 1300 miles of concrete pavement 18 feet wide, and represents an achievement unequalled in any line of the construction industry.

The total amount of new contracts placed during the year was, up to December 1st, in excess of 75,250,000 square yards. The amount of work under contract and uncompleted was, on the same date, over 36,200,000 square yards. Much of this was placed under contract during the late months of the year with the intention of doing as much grading and preliminary work as possible during the winter, and to facilitate the maximum accomplishment during 1923.



COMPARATIVE YARDAGE OF CONCRETE PAVEMENT AWARDED DURING THE YEARS 1916 TO 1922

# The Road That Runs Past My Gate

An Editorial by **Roger B. Whitman**
Courtesy *Country Life*

When I first drove over the road that runs past my gate it was of the kind known as dirt, horribly muddy in the spring and fall, a mass of frozen ruts in winter, and unbelievably dusty in summer; just such a road as lay anywhere off the main arteries.

It ran through a farming section from the town on the railroad to the county seat, and over it passed such traffic as was absolutely necessary—crops on their way to market, the stock of the inadequate general stores, fuel.

It served its purpose as a link in the net-work of commerce, but at the cost of much effort.

Because of a mudhole or two that were ever present, a farmer's team could haul only a half load, although the rest of the road might be firm. there could be no hurrying over that five-mile stretch except at the expense of springs and axles.

Altogether annoying and exasperating, it was accepted as inevitable, and stood as a monument to our local political system.

There have been many changes in the twelve years since that day, and more and more those changes have centered in that stretch of road. It has caught up with the times, and has undergone an evolution that I used to think was the result of our general awakening but that I now see as one of the causes of it. It began by being scraped; then it was surfaced; later it was oiled; and finally, after a tedious upheaval, it developed its present broad and smooth concrete surface. And now, when I consider what it is accomplishing, I marvel that we ever were so blind as not to have foreseen the possibilities of even this little stretch of road.

Road? It is not a road to me; it is a symbol of progress, a means to a vast end.

Where, in the past, it hindered my trips to the next town, it is now the enchanted entrance to the ends of the earth, the beginning of my dream journeyings, the invitation to rove, to see, to know, to expand.

It is the foundation of commerce, the bringer of civilization, the means of contact of farm to farm, of state to state, and of all of the grades and shades between.

It leads to and from all human endeavor; where the children of our lonely neighborhood used to grub over their books in a one-room district school, presided over by a forlorn school-ma'am who taught everything from the A B C's to geometry, now they are gathered by a bus and taken to modern schools in the county seat, to get the most thorough education that can be provided, under the most efficient tutelage.

And it is our road that makes possible this insurance of progress.

To the city it brings the country and the sense of the country's freedom and sincerity and rest; to the country it brings the city's culture and resource and improvement.

A channel for the flow of all that civilizes and develops, it leads our little neighborhood, and so the nation, to unguessed heights of culture and education, of strength and unity and understanding.

**Here's Wishing You a Happy and**
**Prosperous New Year—**
**Plenty of Work to**
**Do and Some**
**Profit**

# How Shall We Build Better Concrete Roads?

## *Outstanding Ideas on the Progress in Design and Construction of Concrete Roads, Contributed by:*

A. T. GOLDBECK, H. E. HILTS, J. S. BOGGS, CLIFFORD OLDER, B. H. PIEPMEIER, H. J. KUELLING, B. S. PEASE, D. S. MACBRIDE, CHARLES J. BENNETT, FRANK F. ROGERS, JAMES ALLEN, E. R. HOFFMAN, PAUL D. SARGENT, R. H. BAKER, H. S. VANSCOYOC, N. F. HELMERS.

### Thicker Edges—Center Joints

BY A. T. GOLDBECK
CHIEF, DIVISION OF TESTS
UNITED STATES BUREAU OF PUBLIC ROADS
WASHINGTON, D. C.

Great progress has been made during the past year looking toward more adequate design of concrete roads for our present day traffic.

The Pittsburg test in California has been completed, and the Bates Road test in Illinois has likewise been loaded to the legal limit. Both of these investigations have shown the desirability of strengthening the edge of the slab. I feel there is no question that the weakest portion of the slab is along the edge, and probably at the corners, and it is surely logical to make this portion at least as strong as the center portion of the slab. This being the case, the desirability of a thickened edge or of increased reinforcing steel along the edge is indicated.

With regard to the use of a center longitudinal joint, one has only to inspect carefully concrete roads in various states to come to the conclusion that such a joint is desirable in some locations and unnecessary in others. In many localities very little trouble is had with longitudinal cracking, and here it would seem unnecessary to provide a center joint. In other localities, where longitudinal cracking is prevalent the economy of the center joint should be looked into.

It would seem to me that more and more care should be exercised in the preparation of subgrades to obtain homogeneity. The matter of smoothness of finish should be strictly enforced in specifications, as this means much in the life of a slab and in economy of operation. The failure of both the Pittsburg test road and the Bates road was progressive from joints or cracks, generally in the direction of traffic. This suggests the desirability of high longitudinal resisting moment, and possibly the use of a much higher proportion of longitudinal steel than transverse steel. Much remains to be learned regarding the proper percentage of steel, and even the proper position.

With regard to the production of standard designs, I feel more and more that the characteristics of the subgrade play a most important part, as do also the loading and climatic conditions. One must expect a lot more subgrade where the soil is of the fine textured plastic variety, capable of the retention of a high percentage of moisture, than where the soil is of a granular, sandy nature. There will be much more movement of the subgrade in freezing climates than in the warmer parts of the country. The nature of traffic is much different near our centers of population than where our towns are widely separated. All of these things affect design, so that there can be no such thing as a standard design equally applicable to these varying conditions. It should be possible, however, to draw up a limited number of standards which will take care of the range of conditions throughout the country. It is true that exact knowledge for the preparation of such standards does not exist, but nevertheless a number of facts have been developed which go a long way toward pointing to proper design for a particular set of conditions.

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### 7 3/8 In. of Concrete and Reinforcement

BY H. E. HILTS
ACTING CHIEF ENGINEER
PENNSYLVANIA STATE HIGHWAY DEPARTMENT
HARRISBURG

#### DESIGN

I do not think we will ever obtain one standard of highway construction, inasmuch as the materials of construction are so variable throughout this country. We may expect standardization possibly as to the design of cross sections and a general standardization as to the grading of materials, but I believe that we will always have local deviations from a general standpoint.

There will probably be a few minor changes in the design of cross sections, but we feel that our present standard of an average of 7⅜ in. of concrete with mesh weighing 65 lbs. per 100 sq. ft., placed 2 in. from the surface, and with ¾-in. round rods at either side of construction and expansion joints, at present loading, gives a fair factor of safety for future development—this section being for primary system work.

For secondary system work, we will doubtless continue to use an average thickness of 6¼ in. reinforced, as detailed above, for our primary system work.

Roads constructed according to the above practice, with minor changes, now have a life of from one to eight years, and give no apparent indication of any vital defects as far as structural design is concerned. Some of these roads have been subjected to exceptionally heavy vehicular traffic.

### Inspection

It would seem desirable to call attention to strict and competent inspection of all aggregates, with particular reference possibly to the fine aggregates. Our experience has been that there is likely to be a scaling of surface if there is an excess of "flour" in the fine aggregates, and we are limiting the use of grits from screenings to those jobs where natural deposits would become available only at excessive cost.

### Construction

In Pennsylvania we have consistently endeavored to standardize construction year by year, with the idea of obtaining more perfect work on the job; and we believe in the importance of strict adherence in the preparation of a sub-grade having a relatively high coefficient of elasticity when rolled; and we believe in the setting of forms at least 500 ft. ahead of the mixer at all times, this length being kept clear of materials; and we are firmly convinced of the desirability of transporting construction materials in batch boxes. We insist on the use of batch meters on all mixers, and a mixing time of one and one-quarter minutes.

I believe that there will be developed in the next few years a well defined and standardized practice of finishing roadways, inasmuch as one objection to many concrete roadways is that of irregular surface.

After careful consideration we have limited the use of expansion joints in our concrete pavements, placing them only at the P. C.'s and P. T.'s of all horizontal and vertical curves at intervals of 150 to 250 ft. apart, on tangents.

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## Thicker Edges—Better Subgrade

By Joe S. Boggs
Kentucky State Highway Engineer
Frankfort

There is still the opportunity for considerable improvement in the design of concrete pavements by use of the knowledge that is now available to us, so that the roads will better withstand the ravages of heavier and speedier vehicles. It is my judgment that we must provide for a greater thickness of slab at the edge of the pavement, and the use of longitudinal bars as well.

More attention must be paid to the minute details of actual construction, more care exercised in the preparation of the subgrade, and to securing as smooth a surface as is practically possible, so that the impact of heavy vehicles will be reduced to a minimum.

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## Thicker Edges—More Rapid Construction

By Clifford Older
Chief Highway Engineer, Illinois
Springfield

We are rather sure the designs now in common use for concrete roads are not the "last word" in concrete road design.

Judging from the Bates Road tests, we are strongly inclined to the belief that the designs heretofore used for rural concrete pavements are not well balanced, in that some parts of the slab have greater strength or load carrying capacity than others. This being true, it follows that a more equally balanced design would either result in much greater carrying capacity or considerable economy in the first cost of construction. Perhaps the eventual design will result in both economy of construction and load carrying capacity. It is our judgment that the Bates Road test has proved beyond doubt that the edges of the ordinary concrete road are much weaker than the mid-portion of the slab. It naturally follows therefore that the edges should be strengthened; and if the mid-portion of the slab proves to be stronger than necessary to carry expected or legally controlled loads it may be made thinner, with a gain in economy of construction. While we know definitely that the edge strength must be increased to produce a balanced design, we do not yet know just how much the edge must be strengthened in order that it may have the same carrying capacity as a given thickness of slab for the mid-portion of the pavement. The above consideration applies to concrete roads built on any kind of subgrade material.

As to variation of design to meet different conditions, we at present have the feeling that if the design is to be varied, the variation should be based upon a classification of highways as to their use by heavy truck units. It is our opinion that this factor is of greater importance than the character of the subgrade soil on which the pavement is laid. We do not now have sufficiently definite knowledge as to the effect of varying subgrade soil conditions to enable us to vary the design rationally to meet such conditions. We do know very definitely the marked effect on a concrete pavement of given design of wheel loads of various magnitudes. If therefore we can forecast—or control by logical legislation—the magnitude of wheel loads, we can at least safely design for such wheel loads by assuming the worst possible subgrade and climatic conditions. This would result in a safe design which, in the light of knowledge that may be developed in future research work on subgrade effects, may be modified for the sake of economy.

As to construction practice, the extraordinary strides that have been made in the past two years are so satisfying as to relieve the intense interest in this factor that formerly prevailed. For example: Previous to the season of 1921, single outfits rarely accomplished the construction of more than six or eight miles per season. During the season of 1921 several single outfits in Illinois laid considerably more than ten miles of pavement and one outfit laid about twenty miles. During 1922 the majority of the single outfits operating in this State laid more than ten miles of apvement during the season, and more than half of them would have put in a greater mileage than 15 miles had the coal strike and subsequent transportation difficulties not been encountered. It is our feeling that greater refinement in construction practice, which would lead to a surface finish more nearly free from irregularities or waves than at present, would be justified; also that further efforts to secure pavement slabs having but very slight variations from the specified thickness would be well worth while.

[The change in road cross section in Illinois, for 1923 work, requiring now a thick edge, tapering to normal slab thickness, at a short distance from the edge, necessitates new construction practice in some details. These are discussed by Mr. Older as follows.—Editor.]

We are advised by one subgrade machinery manufacturer that it has already made the necessary modifications in its subgrade machine and will have one on exhibition at the Road Show in Chicago in January.

No greater accuracy is needed in cutting the subgrade for this section than has been required heretofore in our practice. We built 1400 feet of extensions of this type to the Bates Road, shaping the subgrade by hand and found that hand shaping to the new cross section is neither costly nor difficult. The new cross section of course requires side forms having a total depth of 9 in. At least one firm is on the market with an extension piece merely in the shape of a small channel which may readily be bolted to the bottom of the 7 in. forms heretofore used. On the Bates Road extension we simply bolted 2 x 4 pieces to the bottom edge of the 7 in. forms, thus making up the necessary 9 in. Contractors purchasing new forms would undoubtedly buy 9 in. forms.

## Thicker Slabs—Smoother Finish

By B. H. Piepmeier
Chief Engineer Missouri State Highway Commission
Jefferson City

Field experience seems to indicate that more thought should be given to increasing the depth of concrete pavements and increasing their strength. If a more careful study is given to the grading of aggregates and the mixing of the concrete, less cement may be used and practically the same strength obtained. Apparently there should be more study given to producing a more finely ground cement to produce additional strength at less cost.

Improved machinery has made it possible to build a much smoother surface on concrete pavements than was possible under some of the older methods. Tests have shown that a smooth surface adds materially to the strength of pavements.

Tests have indicated that very little wear on pavement surfaces may be expected under present character of traffic. It is apparent, therefore, that more investigations should be made along the line of increasing the strength of concrete, and increasing the thickness of pavements to insure greater stability and resistance to heavy loads.

## Edges Stronger—Stock Piling Dangerous—Grind Clinker on Job

By H. J. Kuelling
Construction Engineer
Wisconsin Highway Commission
Madison

Each year it is getting more difficult to discuss new ideas, as concrete road construction is becoming more and more standardized, which it should, and engineers are becoming more in agreement on what good practice is. However, there are a few points which may be of interest.

### Design

If there is one thing in design that stands out in the last few years, it is that the edges of our concrete roads are too weak. This is shown by the numerous triangular pieces that have broken off at the joints or at transverse cracks, but, I believe, more especially at the joints. I believe, therefore, that the edges should be increased in strength, either by reinforcement or by being thickened. It is economy that will determine which method should be pursued, or perhaps that both should be pursued. Wisconsin practice for the coming year will be to place a ⅝-in. rod 6 in. from each edge, the rod to be continuous.

I believe the tests made in the last few years have shown that tile drain is not economical or justified, excepting where used to take care of running water or so-called springs.

Transverse reinforcement should be placed where bad underdrainage exists, which is especially in cuts or where fills are widened. I doubt if it is justified to reinforce all roads. It is possible to do too much refining in building a road, as in any other structure.

As to longitudinal joints, I doubt if we have arrived at the stage where we should specify their use entirely. I have yet to find any satisfactory installation of them, and we have been finding some faults with the roads wherein there are longitudinal joints. Their use as a divider of traffic is not satisfactory without further marking, and the marking can be done so much cheaper that there is no comparison; in fact, our mechanical department is able to mark 25 to 40 miles in a day with two men.

One place that we might very well change our specification is in the matter of sand. We can do more to increase the strength of our concrete roads by specifying and obtaining higher grade sand than in any other way. Our sands run from a bare 100% of standard to as high as 180%. I think additional expense in getting stronger sand is well justified.

### Practice

One practice that is being followed more and more commonly is stock piling, a thing that is highly justifiable so far as the progress of the work is concerned. However, I believe this is becoming a more dangerous practice, and some attention should be given to it. I refer to the material segregating itself when placed in stock piles. The center of the pile invariably gathers to it most of the fine material, and even though the car shipments may meet the specifications as to having the fines screened out, the center of a stock pile very often has almost or more than enough sand in it. It would make better concrete in many cases if no sand was added to it. I believe this is a dangerous feature in some of our modern construction.

Another practice that is more or less common, especially in quarries, is the removal of some intermediate sizes of crushed stone. This should not be permitted in any case.

More attention should be paid to automatic measuring of materials, particularly of the fine and coarse aggregate. It should be so arranged that in case of any failure on the part of the measuring device, it would be on the safe side. This applies particularly to the fine aggregate. That is, the measuring device should be so arranged that the maximum quantity that it will hold will be what you want, and in case that it fails in any way, will merely put in a smaller quantity, which will not injure the strength of your mortar.

I believe that the engineers should receive a copy of the mills' shipments of cement, and where fine aggregate is shipped should receive a bill of lading of the cars. This enables them to keep a close check on the proportions. I believe it would be well worth while for states or counties to pay freight on all materials shipped to the job, thus enabling them to get a gross check on all quantities, and also helping the contractor to finance his job.

I believe that the subgrade should in all cases be checked with a gauge of some kind, whether a sub-grade machine or a hand gauge, being immaterial.

I believe that eventually we will strike concrete both ways, that is, longitudinally and transversely.

### Grinding Clinker on the Job

I have been studying for some weeks over a thought I had that might hurry the construction of our concrete roads. This thought is somewhat revolutionary, but I believe it is at least worthy of passing notice. I am referring to the idea of shipping clinker rather than cement. I believe it is possible to work out a scheme whereby this clinker can be ground at its destination in a satisfactory way and thus obviate some of our troubles. Such a scheme would not necessarily cheapen the work, but would assist in several ways. It would undoubtedly cost more to grind it on the ground, but this would be compensated somewhat by a reduced freight rate, as clinker may be shipped in any kind of rolling stock, at any time of the year. This method would take the peak off the shipping load of the manufacturer. The contractor could ship his clinker in the early spring and then need have no fear of car shortage or shortage of cement, both of which are bound to come. Just what the grinding plant would cost for one or two jobs I am not in a position to state, but at the present time am investigating.

## Ten Points to Consider

By B. S. Pease
American Steel & Wire Co.
Chicago

It is true, our present methods are not uniform, although there has been a great deal of thought expended on the various subjects involved. In general, the points that have been covered in the investigations made have been as follows:

1.—Sub-grade preparation including drainage.
2.—Suitable aggregate.
3.—Proper mixture.
4.—Slab section.
5.—Joints.
6.—Surface finish.
7.—Curing.
8.—Reinforcement.
9.—Job methods.
10.—Allowable truck loads.

Opinion as to sub-grade preparation has been fairly well crystalized and can be standardized.

Suitable aggregate involves considerable variation due to local conditions, but with the knowledge that we now have, limiting values at least can be covered.

Proper mixture will, of course, vary in many cases because of the varying local conditions as to aggregate. Much valuable information has been collected and limiting values can be specified.

A number of ideas as to slab section have been incorporated in actual construction varying from uniform slab thickness for thin and for thick sections to greater thickness at the center line than at the edges, and more recently to a thicker section at the edges than at the center line. At the present time this seems to be one item that is still in the experimental stage.

In the past, joints have been constructed longitudinally as well as transversely, although present ideas as to the latter are fairly uniform for elimination except construction joints when necessary to stop work. Longitudinal joints at one time were quite generally used in street pavements but later discarded because of the extra cost, lack of efficiency and elimination of the necessity, where the pavement was reinforced with a suitable wire fabric. The use of the longitudinal center joint for concrete highways is now in the experimental stage, and in actual practice has not as yet definitely demonstrated either its advantages or its disadvantages. We do know, however, that it has not eliminated the need for a suitable reinforcement and that its cost in place does not vary to any great extent from that for a wire fabric reinforcement weighing 40 to 50 pounds per 100 sq. ft.

Methods of surface finishing are or can be standardized. The same can be said for curing.

Some of the job methods are in the experimental stage, especially those covering the use of central mixing plants, etc.

To a certain extent the method of reinforcing is not definitely standardized although, with few exceptions, our present practice includes some type of reinforced concrete construction. Quite naturally the one thought of economy has been uppermost in the minds of highway officials and until the necessity for reinforcement forced itself to the front by actual experience, the saving secured by its elimination made a strong appeal. Fully realizing the advantages secured by the use of a proper reinforcement, they were confronted with the question of holding first costs to a minimum. This question of low first cost is still a vital one but it has been proven that the elimination of reinforcement is not the next and only way of solving this feature. The subject of reinforcement is, of course, allied with that of slab sections and joints as well as allowable truck loads. It involves not only the amount but also the distribution of the reinforcement members in the slab. Up to date no other type of reinforcement has economically and efficiently equalled a comparatively close meshed wire fabric such as has been continually and successfully used under all types of conditions during the last 12 years. Probably a greater percentage of the reinforced concrete pavements and roadways constructed during that time includes a light wire mesh weighing 25 to 30 pounds per 100 sq. ft. More recently, however, much heavier material has been used but I believe this tendency has been carried too far from the standpoint of economy and necessity. By the use of a 40 to 50 pound wire fabric, the present expensive center longitudinal joint can be eliminated and better results obtained without additional expense.

The outstanding feature today in practically all concrete road projects is the use of some form of reinforcement, and I think we are rapidly coming to the point where this feature can be fairly well standardized.

## Pavement Bases as Good as One Course Concrete

By D. S. MacBride
District Engineer, Portland Cement Association
Philadelphia

The year just ending has witnessed great strides in development of concrete pavement through the use of full size test models, such as the Bates road at Springfield, Ill. These and the tests at Pittsburgh, California, last year have conclusively established three principles which in the past have been subjects of controversy:

First: There is a minimum thickness of slab below which it is not safe to go, due to the necessity of providing a mass with sufficient inertia to resist the impact from traffic. The addition of steel will not reduce this minimum thickness.

Second: Rather than being the thinnest part of a pavement cross section, the edges should be at least as thick and possibly thicker, than the maximum depth at the centre line.

Third: A base under a bituminous or block surface should approach the characteristics of a one-course pavement more nearly than has been heretofore realized.

It is generally admitted that 6 in. is an absolute minimum of thickness for light motor car traffic, that 7 in. constitutes a minimum for medium highway traffic, and that under extremely heavy truck or motor traffic the slab depth required may vary from 8 in. to 10 in. The foregoing statement cannot always apply in a given case, due to variations in the soils and climatic conditions, but will hold true in the majority of instances. Reinforcement is not a substitute for slab thickness, but should be used to safeguard the pavement from destruction at its weakest points and under sub-grade conditions which are unusually severe.

Increased knowledge of soils and improved methods for the preparation of the sub-grade make it no longer necessary to provide the greatest slab thickness at the center line. In adhering to the flat sub-grade cross section the edges have been neglected, 6 in. at the edge to 8 in. at the centre, or an excessive quantity of material, 8 in. to 10 in., used. In view of the Bates tests, the most conservative engineers are looking with favor upon cross sections having uniform thickness, while the pioneers are adopting a section having edges thicker than the body of the slab.

A strange inconsistency has existed in the past in pavement design. The addition of a surface which of itself possesses little or no structural value, has been advanced as a reason for reducing the thickness and strength of a concrete base below the minimum requirement agreed upon in one-course pavement design. The Bates road tests have indicated that the minimum requirement for a base under a bituminous top is identical with the minimum requirement for a one-course pavement and that the minimum for a base under a brick pavement with bituminous filler, is little different, if any, from that required under a bituminous pavement.

The center longitudinal joint, either concealed or exposed, which was developed during 1921, is apparently coming into its own. There seems little doubt that this type of construction, either with or without dowels, will become a standard feature for pavements 18 ft. or more in width.

## Non-Skid Surface

By Charles J. Bennett

Connecticut Highway Commissioner

Hartford

I am rapidly coming to the opinion that we must make some changes in our design of concrete roads, and that this change will inevitably result in the construction of a heavy concrete base of sucffiient thickness to distribute the load properly, and on this concrete base we must place either a plastic or elastic top properly designed, or such a material as will provide a non-skid surface and not scale under traffic.

## Thicker Slabs, Reinforced

By Frank F. Rogers

Michigan State Highway Commissioner

Lansing

Knowledge recently gained, especially during the tests of the Bates Experimental Road at Springfield, Ill., which coincides fairly well with observations under actual traffic conditions in Michigan has proved:

(1) The fallacy of making concrete thin at the edges and thick at the center. In fact, they have positively proven that just the reverse of this would have been better practice.

(2) That thickened edges reinforced with longitudinal bars, with the center of the slab thick enough to withstand ordinary trucking traffic, would have been a more reasonable design.

Illinois has concluded that 6 in. in the center of the slab is sufficient, but experience on the Dixie Highway in Michigan would indicate the danger of a slab so thin as that, which is liable to break down at expansion joints, if any are used, and at transverse cracks, if no joints are used.

Longitudinal joints doweled together seem desirable on all pavement 18 ft. or more in width.

Much more pains is now taken than formerly to get a stiff mix of concrete; in fact, so stiff that it cannot very well be finished without the use of a mechanical finisher. Much more pains is now required in use of straight edges and very careful inspection to insure a more perfect mechanical job, and thus get a pavement with almost perfect riding qualities. Batch meters on the mixer insuring a full minute mix, have also contributed much to a better grade of concrete.

## Design Is a Local Problem

By James Allen

Supervisor of Highways

and

E. R. Hoffman

Engineer of Materials

Washington Division of Highways

Olympia

The design of concrete pavements must be based on a clear understanding of the soil, drainage, climatic conditions and the definite maximum limit in the loading of the truck traffic and type of truck; that is, whether it shall be four or six-wheel vehicles or even more, as we now have on the highways. Any attempt to design concrete pavement without taking all these matters into consideration, particularly the maximum size truck, will not be economically successful. The public certainly cannot afford to pay for pavement that will withstand the traffic of the largest truck that anyone may care to operate, nor is there occasion for them to do so, as the excessively loaded truck can and must be eliminated. There is no reason why tremendous sums of money should be invested to accommodate what would be a comparatively small amount of traffic. If a highway were designed for a 12-ton loading, with definite specifications as to the number of axles and their spacing, practically all the traffic would naturally come within this limit. There would, however, be a small amount of traffic that would run up to twenty or thirty tons per vehicle, and there is certainly no justification in spending money that would accommodate traffic in excess of twelve or fourteen tons.

It will be impossible to design a definite type of pavement that can be used satisfactorily and economically in all sections of the country. We have in our own state various soil and climatic conditions that require a different type of pavement to carry the legal traffic and withstand the climatic conditions. The type of pavement necessary in the North Central states would certainly be different from the type of pavement in the South, where there is practically no frost action, even though loads to be carried and sustaining power of the soil were the same. From the studies and investigations that are now being carried on it may be possible to lay down broad principles for general design. They must, however, be adapted to local conditions after a thorough study of all the factors that enter into the destruction of the pavement.

Changes in the construction of a road would not appear to be likely. Contractors in this locality have developed a plan of construction that produces a large yardage at a comparatively small cost. The most difficult problem is and has always been the problem of getting the fine and coarse aggregates to the mixer. After this is done the matter of placing the concrete is very well standardized. A great variety of schemes have been tried, and as a result construction methods have simmered down to one plan of construction in this locality. It is possible, however, changes in the design may necessitate detailed changes in the scheme of construction, but it seems likely that the general broad principles will not be changed.

## Good Concrete on Gravel Base

BY PAUL D. SARGENT
CHIEF ENGINEER MAINE STATE HIGHWAY COMMISSION
AUGUSTA

We build a very limited amount of concrete, not more than eight or ten miles in each of the last two years. We have attempted only to follow best pratice which the experience of other states has developed. Our work this year has all been laid with a center joint, with rod reinforcement of about 8-7/10 lbs. per sq. yd., and substantially all of our concrete pavement has been laid on an eight inch gravel base.

We have some concrete pavement ten years old, limited areas to be sure, but all of this pavement that was laid on old gravel roads or on a new gravel base has been satisfactory from the viewpoint of not cracking, although some of it is as thin as five inches. Our standard section this year has been seven inch uniform section.

Some of our contractors have used the central mixing plant and others have used the mixer on the sub-grade. We have somewhat inclined to the belief that the jobs mixed from the central plant have proven to be smoother. I cannot say that this could be traced to the fact that the concrete had been mixed and hauled a mile or so. No appreciable difference in the speed of laying has been observed between the two methods.

## Graded Standards

BY R. H. BAKER
ASSISTANT TO CHIEF ENGINEER
TENNESSEE DEPARTMENT OF HIGHWAYS, NASHVILLE

Standards for concrete road construction in Tennessee are graded according to locality, traffic weight, and traffic density, character of sub-soil, and other items which enter into the proper consideration of highway transport.

The Tennessee Department of Highways requires a minimum thickness of 7 in. on all concrete roads, with a uniform cross-sectional thickness. The most recent obtainable results of tests are, however, tending to change our practice to a pavement slightly thicker at the edges than in the center. On all pavements more than 16 ft. wide the department requires a longitudinal expansion joint.

Such changes as are deemed necessary by a careful determination of the percentage of water by slump test or otherwise, and the careful measurement and mixing of aggregate made on each particular job are incorporated into the work, in order that a more nearly uniform and longer slab life may be obtained.

## Use Longitudinal Joints—Better Concreting Practice

BY H. S. VAN SCOYOC
CANADA CEMENT COMPANY, LIMITED
MONTREAL

This year's experience has tended to confirm a belief that some changes in the design of concrete roads is desirable.

One proof of it is the success of the central joints limiting the slab to the width of 10 ft. The other is the improved results of adding reinforcing of satisfactory strength at those portions of the slab where stresses are greatest.

The application of the best principles of highway construction that are being increasingly used in building construction will tend to produce concrete more uniformly of the high grade which is necessary in highway construction. We refer to a very careful investigation of materials to be used and determining from this investigation of the actual strength which can be anticipated and the carrying through on the actual job of methods which will give properly cured concrete of the previously determined proportions and consistency. This would include tests of the concrete as it is placed to definitely determine whether the results are as anticipated.

## Better Subgrade Drainage—Eliminate Handling on Subgrade

BY N. F. HELMERS
SIEMS, HELMERS & SCHAFFNER, CONTRACTORS
ST. PAUL, MINN.

More thought should be given to sub-grade drainage or possibly some type of ballast on which the pavement should be laid. The "fine grading" now required in many soils costs as much as a thin layer of ballast which could be more easily shaped and would give a better structural condition. The question of expansion joints, particularly one of smooth riding quality should also be given much more study.

Study of actual working conditions on various roads of this State leads the writer to the belief that in order to secure high quality and consequently longer life, it will be necessary to eliminate the hauling of material on the sub-grade by trucks. This particularly gives a compacted center and in many cases induces unequal settlement. The use of the so-called central plant wet batch in some soils gives a bad sub-grade condition and in many cases bad concrete due to the earth lip at the side of the rut mixing in the concrete. The largest road building county (St. Louis) has arbitrarily ruled off all types of haulage that involve any of the above conditions making it practically necessary for the contractor to use industrial track haulage which of necessity gives a sub-grade unaffected by the above items subject to thorough inspection and permits the placing of a high-class concrete pavement. Indications are that this attitude will spread.

## Must Learn More Before Adopting Standards

A. W. DEAN
CHIEF ENGINEER MASSACHUSETTS DIVISION OF HIGHWAYS
BOSTON

I do not consider that sufficient experience in concrete road construction has yet been had to warrant establishing any standard cross sections, notwithstanding experiments which have been made in several states. Changes in job practice are constantly being made everywhere, and it is my opinion that it will be at least two years more before any standard sections or standard practice in construction can be adopted.

# Maintenance Costs on New York State Highways, 1921

Valuable highway maintenance cost records are given in the annual report of the State Commissioner of Highways of New York for the year 1921. The accompanying table of maintenance costs offers comprehensive data. Herbert S. Sisson is Commissioner of Highways for New York, and the work of Maintenance and Repair is under the direction of the Second Deputy Commissioner, H. G. Hotchkiss, Jr. The following textual excerpts and tables are quoted from the report of the Second Deputy Commissioner.

Submitted herewith will be found a table giving the maintenance cost per mile per year for the various types of improved roads in the state. The last column gives the cost per mile of expenditures on the paved portion only. The fourth column gives the cost per mile for all work. but does not include reconstruction costs when a type is changed. The third column gives the same except that the cost of replacing the old road by a new type is included and charged against the old type. This column is merely for general information. The last two columns of this table on types which have a length of twenty-five miles or more are very valuable. The rest should be used with caution, as its chief value is in making a cumulative record rather than in the record for any one year.

AVERAGE ANNUAL MAINTENANCE COST PER MILE OF PRINCIPAL TYPES FOR THE PAST SEVEN YEARS, INCLUDING CHANGE OF TYPE

| | 1915 | 1916 | 1917 | 1918 | 1919 | 1920 | 1921 | Ave. |
|---|---|---|---|---|---|---|---|---|
| Bituminous macadam, penetration method, asphalt and tar.... | $ 510 | $ 483 | $ 408 | $ 557 | $501 | $590 | $753 | $543 |
| Topeka on concrete base .............. | .... | 205 | 245 | 435 | 144 | 335 | 299 | 277 |
| Topeka on macadam base .............. | .... | 256 | 393 | 1,056 | 443 | 985 | 769 | 650 |
| Waterbound macadam ............ | 1,055 | 906 | 970 | 739 | 694 | 797 | 951 | 873 |
| Brick .............. | 190 | 176 | 222 | 251 | 247 | 242 | 307 | 234 |
| First-class concrete.. | 129 | 141 | 112 | 160 | 214 | 227 | 225 | 173 |
| Second-class concrete ............ | 1,050 | 1,080 | 1,127 | 791 | 761 | 868 | 874 | 936 |
| Gravel ............ | 955 | 587 | 918 | 909 | 771 | 704 | 890 | 819 |
| Average, all types. | $750 | $651 | $643 | $608 | $560 | $631 | $744 | .... |

The foregoing table gives the average cost per mile for maintaining the eight types of greatest mileage for the past seven years and covers a mileage varying from 5,400 to 8,000 miles for the various years. All overhead and general expenses of every nature have been pro-rated in proportion to the money spent on each type. The table does not include reconstruction costs, but it is the best information available in this country on the important subject of state and county highway maintenance cost. It may be taken with confidence as the average cost of keeping these types in the average condition found on New York state and county highways.

| Type of Pavement | Miles Maintained | | Cost per Mile | | |
|---|---|---|---|---|---|
| | Including change to more durable type | Excluding change to more durable type | Including change to more durable type | Excluding change to more durable type | Pavement only, excluding change to more durable type |
| Bituminous macadam penetration method, macadam base, asphalt binder...... | 3,201.87 | 3,186.82 | $1,033 | $ 770 | $ 581 |
| Tar binder ................ | 255.06 | 255.03 | 543 | 540 | 341 |
| Concrete base, asphalt binder | 45.21 | 45.21 | 560 | 560 | 446 |
| Tar binder ................ | 16.81 | 16.81 | 363 | 363 | 250 |
| Waterbound macadam ...... | 2,599.04 | 2,536.29 | 2,007 | 951 | 813 |
| First class concrete, 1:2:4 mix or richer ............ | 730.45 | 730.45 | 225 | 225 | 81 |
| Second class concrete, 1:2½:5 mix or leaner........... | 187.65 | 181.50 | 1,957 | 874 | 710 |
| Hassam concrete ........... | 49.03 | 49.03 | 679 | 679 | 395 |
| Brick pavement ............ | 280.45 | 280.19 | 352 | 307 | 226 |
| Gravel ..................... | 141.14 | 136.30 | 1,861 | 890 | 767 |
| Bituminous macadam mixed method: | | | | | |
| Topeka concrete base...... | 65.42 | 65.01 | 831 | 299 | 128 |
| Topeka macadam base..... | 29.72 | 29.72 | 769 | 769 | 354 |
| Amiesite concrete base..... | 6.25 | 6.25 | 440 | 440 | 215 |
| Amiesite macadam base.... | 4.88 | 4.88 | 53 | 53 | 10 |
| Open mixed concrete base. | 17.09 | 17.09 | 413 | 413 | 166 |
| Open mixed macadam base. | 15.43 | 14.68 | 3,869 | 462 | 288 |
| Bitulithic concrete base.... | 15.12 | 15.12 | 244 | 244 | 231 |
| Warrenite-Bitulithic ........ | 1.81 | 1.81 | .... | .... | .... |
| Willite, concrete base....... | 1.66 | 1.66 | .... | .... | .... |
| Bitoslag, concrete base...... | 2.31 | 2.31 | 37 | 37 | .... |
| Sheet asphalt, concrete base. | .61 | .61 | 229 | 229 | 229 |
| Gravel mixed, gravel base... | 8.38 | 7.72 | 5,154 | 1,978 | 1,757 |
| Henderson, macadam base... | 0.51 | 0.51 | .... | .... | .... |
| Block pavements: | | | | | |
| Asphalt, concrete base..... | 18.34 | 18.34 | 347 | 347 | 214 |
| Asphalt, macadam base.... | 1.73 | 1.73 | 1,271 | 1,271 | 1,082 |
| Wood ..................... | 0.26 | 0.26 | .... | .... | .... |
| Stone .................... | 3.58 | 3.58 | 9 | 9 | .... |
| Brick cubes, macadam base | 0.32 | 0.32 | 104 | 104 | 104 |
| Bituminous sub-base ........ | 15.70 | 15.70 | 332 | 332 | 266 |
| Bituminous macadam, three layer method ............. | 7.29 | 7.29 | 734 | 734 | 448 |
| Kentucky rock asphalt....... | 17.55 | 17.55 | 686 | 686 | 614 |
| Rocmac ..................... | 0.15 | 0.15 | .... | .... | .... |
| Three-strip dual ............ | 6.81 | 6.81 | 134 | 134 | 120 |
| Two-strip dual ............. | 33.99 | 31.69 | 1,562 | 332 | 146 |
| Total .................. | 7,781.62 | 7,688.42 | .... | .... | .... |
| Average cost per mile. | ...... | ...... | $1,280 | $744 | $582 |

*Major Besson's article aims at facilitating the predetermination of strength in concrete by more complete use of the knowledge we now have of the factors of quality in the material.*

# Design of Concrete Mixtures

By F. S. Besson
Major, Corps of Engineers, U. S. A.
(Copyright 1922 by F. S. Besson)

## Quality of Concrete

In the past concrete mixtures have most often been arbitrarily specified without knowledge of the true strengths resulting from the use of any stated proportions of the given materials. The wide field in which it is used, and the ease with which it can be handled by unskilled persons, and still give temporary superficial good appearance, has led to much abuse of concrete as a paving material. Roadway concrete is subject to large temperature changes, alternate wetting and drying, and the pounding of traffic. Every effort is accordingly justified to produce a superior product; and in this spirit there has grown up on the part of those having to do with specification standardization a tendency to specify quality by "consistency" and "strength" rather than by proportions such as "1:2:3." An example of such a proposed specification is as follows:

> *Quality*—The quality of concrete shall be expressed in terms of workability as determined by the slump test and of the compressive strength at 28 days, as determined by concrete tests of the materials to be used. The proportions required to produce concrete having the strength specified shall be determined in advance of the mixing of the concrete.
>
> *Strength*—The concrete shall develop under the conditions specified in the preceding section, for the various parts of the work, the following strengths: (the engineer to insert the strengths required)

In specifying "quality" it is contemplated that in order to obtain a desired strength the proportions to be used in concrete mixtures shall be determined either by the engineer or by the contractor, or else in accordance with certain published tables; but in any case, upon failure to meet the specifications such changes are required to be made in the materials, proportions or mixing as may be necessary to secure concrete of the desired strength.

Contractors feel that this strength requirement places an undue burden upon them. They believe that the present state of the art is such that a specified strength cannot be guaranteed, and that it is the duty of the engineer to take the chances involved in attempting to produce a given strength. Concrete is a job-made material and results obtained depend upon a great number of variable factors. Even under favorable laboratory conditions the strength of cylinders taken from a single mixture varies greatly and also different laboratories testing identical materials may obtain widely different results. The main problem of proportioning is to coordinate laboratory and field control so as to develop a workable practice.

The contractor's interests can be guarded, if it is desired to specify concrete of a given strength by payment on a sliding scale, for instance, dependent upon the amount of cement used per square yard of pavement. If aggregates are used that are well known to the engineer, he may, by stipulating certain proportions for his work, obtain concrete of satisfactory strength. On the other hand, if the contractor imports aggregates

PERCENT PASSING EACH SIEVE AND RETAINED ON THE NEXT SMALLER

| SIEVE NO. | 1½ | ¾ | ⅜ | 4 | 8 | 14 | 28 | 48 | 100 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| SIZE IN MILLIMETERS | 3810 | 1880 | 940 | 470 | 236 | 117 | 059 | 0295 | 0147 | |
| PERCENT | 4 | 7 | 7 | 5 | 7 | 11 | 25 | 20 | 14 | 100 |

TOTAL PERCENT COARSER THAN EACH SIEVE

| SIEVE NO. | 1½ | ¾ | ⅜ | 4 | 8 | 14 | 28 | 48 | 100 | SUM |
|---|---|---|---|---|---|---|---|---|---|---|
| PERCENT | 0 | 4 | 11 | 18 | 23 | 30 | 41 | 66 | 86 | 279 |

| SIEVE NO. | FINENESS MODULUS SUMMATION OF VERTICAL RECTANGLES | ARITHMETICAL PROGRESSION SUMMATION OF HORRIZONTAL RECTANGLES |
|---|---|---|
| 100 | 0.86 | 20 x .01 = 0.20 |
| 48 | 0.66 | 25 x .02 = 0.50 |
| 28 | 0.41 | 11 x .03 = 0.33 |
| 14 | 0.30 | 7 x .04 = 0.28 |
| 8 | 0.23 | 5 x .05 = 0.25 |
| 4 | 0.18 | 7 x .06 = 0.42 |
| ⅜ | 0.11 | 7 x .07 = 0.49 |
| ¾ | 0.04 | 4 x .08 = 0.32 |
| 1½ | 0.00 | 0 x .09 = 0,00 |
| TOTAL | 2.79 | 2,79 |

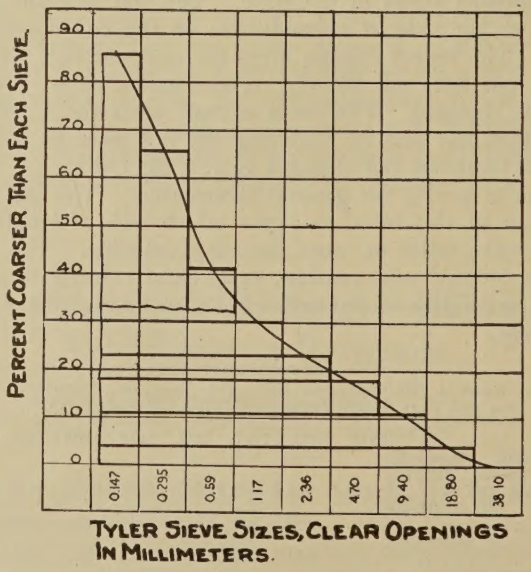


Fig. 1—Adding Up the Two Parallel Columns Shows that Since the Sum of the Horizontal Rectangles Gives the Same Amount as the Fineness Modulus, the Latter is Equivalent to Weighting the Per Cent of Aggregate Retained on each Sieve in Accordance with an Arithmetical Progression, the Common Difference Being 1/100 as the Sieve Sizes Increase

which are entirely new to the engineer, something more than an arbitrary requirement as to proportions is necessary. Any plan that helps to insure concrete of a predetermined strength and quality is a step in the right direction. If concrete is placed in a roadway and then 28 days later a compression test shows that the specification as to "quality" is not fulfilled, a difficult situation develops. For many years investigators have searched for some measure that could be applied to materials prior to actually making concrete of them, and which would foretell strength.

### Fineness Modulus

The fineness modulus method of measuring aggregates in order to determine how much cement and water to use, in order to obtain specified strengths, is set forth by Professor Abrams in Bulletin No. 1, April, 1919, of the Structural Materials Research Laboratory, Lewis Institute. The scheme is based upon the cumulative plot of the mechanical analysis of aggregates. In Fig. 1, using a logarithmic horizontal scale, the curve represents an aggregate with the per cent coarser than each sieve plotted against mesh openings in millimeters. Assuming each of the vertical rectangles to have a width of 1/100 of a unit, their summation, giving the area beneath the curve, amounts to 2.79, the fineness modulus of the aggregate. The summation of the horizontal rectangles amounts to the same, but in addition is equivalent to taking the ordinary sieve analysis and weighting the per cent retained on each sieve, after having passed through the next larger, in accordance with an arithmetical progression, the common difference being 1/100 as the sieve sizes increase. (That passing the smallest sieve is weighted zero.) It is evident as illustrated by the summation of the horizontal rectangles that the fineness modulus scheme is an empirical one which arbitrarily gives more weight to the larger particles making up aggregates. Accordingly, there must remain a doubt as to the universal applicability of the method to the proportioning of specific mixtures.

Also, the volume of space occupied by the cement, using any one set of aggregates and a fixed quantity of cement, increases (for wet mixtures ordinarily used) as the water is increased, which means that strength decreases as the water is increased. A given ratio of water to cement corresponds to a fixed strength. The addition of excess water in order to obtain a desired consistency or workability reduces strength and, therefore, to obtain the desired consistency, maintaining strength constant, it is necessary to increase both cement and water. In other words, the basic element of the theory is that for given strength the water-cement ratio must be kept constant.

### Surface Area

In the 1918 A. S. T. M. Proceedings, L. N. Edwards describes "Proportioning the Materials of Mortars and Concretes by Surface Areas of Aggregates." Since that time Messrs. Young and McCarthy, of the Hydro-Electric Power Commission of Ontario, have used the surface area method as an aid in work carried on by the Commission. In computing surface areas, the grains of mineral aggregate are assumed to be either cubes, spheres or other shapes, in formulae relative to which a mean diameter and certain constants enter. When a granulometric analysis has been made, the various mesh sizes are assumed to be the mean diameters. The number of grains in a net volume of matter passing through any one sieve depends upon the volume of each grain, that is, the number varies inversely as the cube of the mesh diameter. The area of each grain varies as the square, and therefore the total areas of the volumes through the sieves vary inversely as the sieve diameters. Then, if each sieve mesh has openings one-half those of the next larger sieve, the weight attached by the surface area scheme to the volume through each sieve would be as in the following table, where comparison is made with the fineness modulus scheme.

| | | Fineness Modulus | Surface Area |
|---|---|---|---|
| Sieve No. | Per cent passing and retained on the next smaller | Weighted by Arithmetical Progression | Weighted by Geometrical Progresion |
| 100 | 14 | .......... | 14 x 2.56 = 35.84 |
| 48 | 20 | 20 x .01 = .20 | 20 x 1.28 = 25.60 |
| 28 | 25 | 25 x .02 = .50 | 25 x .64 = 16.00 |
| 14 | 11 | 11 x .03 = .33 | 11 x .32 = 3.52 |
| 8 | 7 | 7 x .04 = .28 | 7 x .16 = 1.12 |
| 4 | 5 | 5 x .05 = .25 | 5 x .08 = .40 |
| ⅜ | 7 | 7 x .06 = .42 | 7 x .04 = .28 |
| ¾ | 7 | 7 x .07 = .49 | 7 x .02 = .14 |
| 1½ | 4 | 4 x .08 = .32 | 4 x .01 = .04 |

Fineness Modulus = 2.79. Surface Area Factor = 82.94.

The numerical value of the surface area depends upon the units and constants assumed in its computation. It may, however, be represented by a factor as illustrated in the table. The volume through each sieve is weighted in accordance with a geometrical progression, the first term, representing the 1½-in. sieve, being .01, and the common ratio being 2 as the the sieves become smaller, until a weight of 2.56 is attached to the No. 100 sieve. The Fineness Modulus method gives no weight to the material passing through the No. 100 sieve, while the surface area method attaches maximum weight to this material. There is no relationship between fineness modulus and surface area except that, as the former increases the latter decreases. When the one is a maximum the other is a minimum. Thus we find that in evaluating an aggregate, though the two methods might interpret its cement and water requirements equally, the one would give the aggregate a high numerical value and the other a low value. Each is an empirical method and neither is general enough in application to produce a guaranteed strength for concrete.

### Methods by Voids

For many years (Feret published the results of his studies in 1892) engineers have tried to establish rules for proportioning concrete on a relationship between cement, voids and strength. In general the void method asserts that the densest and strongest concrete that can be made with any proportion of cement and any combination of aggregate is that in which the cement paste fills the voids of the sand and the resulting mortar fills the voids in the coarse aggregate. From 1904 to 1907, Mr. W. B. Fuller (Trans. A. S. C. E., 1907) developed his maximum density curves, which call for artificial grading of aggregates in accordance with specified sieve analyses in order to obtain concrete of maximum density. Very recently Professor G. M. Williams (*Journal of the Engineering Institute of Canada*, 1921) carried out tests giving results in which the highest strength was not found for concrete having maximum density. He states instead, that, considering material from any one source, the combination of dry sand and coarse aggregates having the greatest unit weight generally produced the strongest concrete; but he proposed no method of predicting the strength that would result when using given quantities of cement and aggregate. Professor Talbot shows in the A. S. T. M. Proceedings, 1921, a relationship between strength and the space occupied by cement paste in the wet mixture. As a means of predicting either of these two elements, he proposes to measure the space occupied by cement paste in mixtures made without the coarse aggregate; that is, the fine aggregate alone is used.

Though the studies that have been made by the several investigators whose methods have been outlined, and by many others, have been a material step forward, further research and experience are necessary. Schemes based either on granulometric or voidage measurements, either of dry aggregates alone or of dry aggregates plus cement, all fail to take into consideration changes in volume caused by the addition of water, as illustrated in Fig. 2, and therein they fail as indices of concrete strengths. Usually the choice of aggregates is a simple matter, because restricted to those locally available. The main problem is to combine the available sand and coarse aggregate in such manner as to give the best concrete for the least money and satisfactory for the work in hand; the process of doing which will be illustrated in the following paragraphs.

*Measuring Ingredients*—First of all, it is necessary to adopt such methods of measuring ingredients for concrete as will insure compliance with the designs of the engineer. For the laboratory A. S. T. M. methods are followed. For field work the 1921 progress report of the Joint Committee representing the A. S. T. M. and several other engineering and commercial bodies proposed:

*Unit of Measure*—The unit of measure shall be the cubic foot. Ninety-four pounds (one bag or ¼ bbl.) of portland cement shall be considered as one cubic foot.

*Method of Measuring*—Each of the constituent materials shall be measured separately by volume (weight). The method of measurement shall be such as to secure the specified proportions in each batch. If volume measurement is used, the fine aggregate and the coarse aggregate shall be measured loose as thrown into the measuring device. The water shall be measured by an automatic device that will insure the same quantity in successive batches.

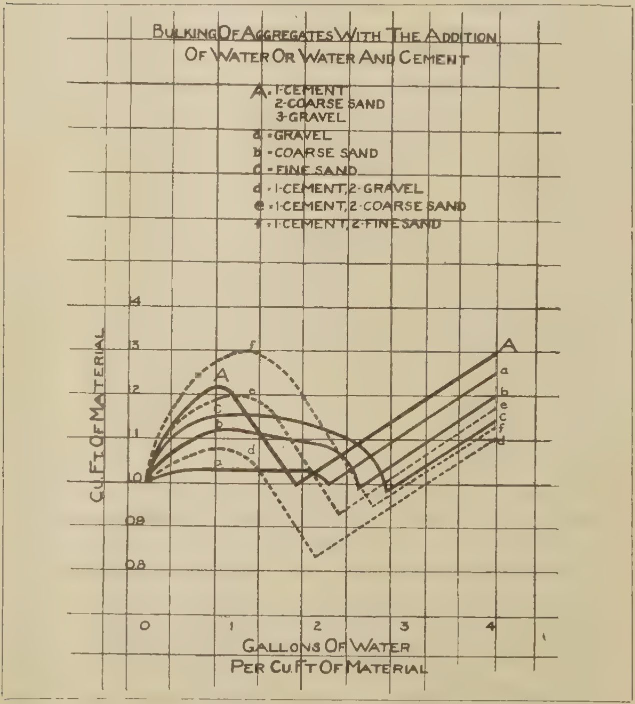


Fig. 2—Mixtures Puddled in 3 Inch Layers with a Steel Rod. With the Addition of Water, Volumes First Increase then Decrease. The Points of Minimum Volume with Cement Mixtures Give Maximum Strengths. These Points Represent Slumps of About 1 Inch. The Addition of Water After the Point of Minimum Volume Is Reached Increases the Bulk in Amount Equal to the Volume of the Added Water

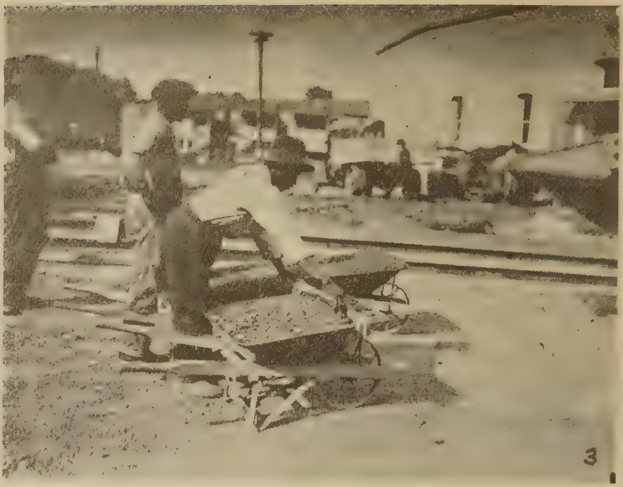


Fig. 3—Aggregate When Charged by Wheelbarrows Should be Struck Off Evenly by Means of Templates as Illustrated

## Measuring Aggregates

Referring to Fig. 2, it may be understood that the presence of moisture influences the measuring of aggregates, not so much in the case of coarse materials, but to a large extent in the case of sands. Assume that on account of rain, or the receipt of sand fresh from the dredge, it has a bulk 20% greater than when dry. Then a cubic foot of sand actually measures 1.2 cu. ft., and if a 2 cu. ft. barrow is struck off level it will contain but 1 2/3 cu. ft. of sand, and instead of a 1:2:3 mixture, for instance, a proportion of 1:1 2/3:3 would be obtained. This generally means that more cement per square yard of pavement is used than was estimated for, and on that account it is on the side of safety as far as strength is concerned; but the decrease in the sand might give a mixture not quite as easily brought to a surface finish as that contemplated by the original design. In the tests described in subsequent paragraphs aggregates were measured at room dry conditions, the moisture present being less than ½ of 1%, by weight, and, therefore, immaterial.

When a central proportioning or mixing plant is used, with bins and measuring boxes, no trouble need be experienced in obtaining all necessary accuracy in measuring aggregates. Wheelbarrow charging of mixers, however, is far from being obsolete. If the use of barrows is not closely supervised, leaner concrete than specified invariably results. Specifications should require barrows to have sides not more than two feet apart, and to be of such capacity that when struck off with a template, as illustrated in Fig. 3, they will contain the exact volume required. When barrows are required to carry a ¾ load or a heaping load, very indefinite measurement results.

## Water-Cement Ratio

Professor Abrams, in his Bulletin 1, shows a relation between compressive strength and water content for 28 day tests of 6 x 12 cylinders. Mixes from 1:15 to neat cement were used; each mix was made up of aggregates ranging in size from 14 mesh sand up to 1½-in. gravel; a wide range in consistencies was used for all mixes and gradings. The water content was expressed as a ratio to the volume of cement. Carrying out this scheme with various combinations of District of Columbia aggregates, and plotting compressive strength against gallons of water per bag of cement, a smooth curve was obtained, Fig. 4, which is practically identical with that of Professor Abrams.

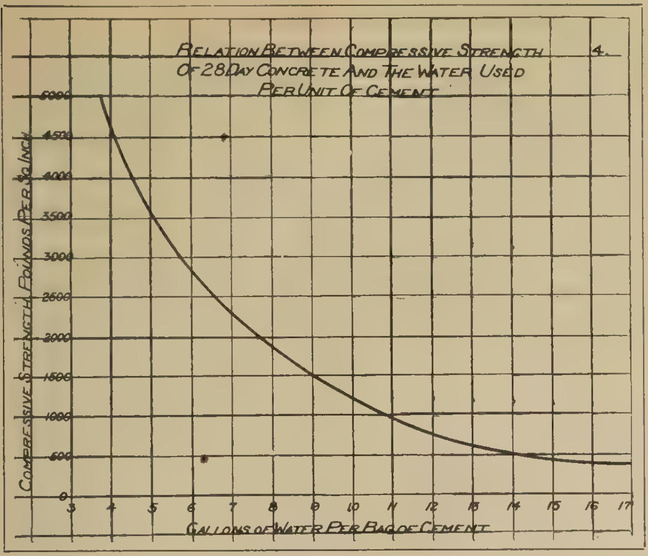


Fig. 4

With this curve and by simply noting the gallons of water used for each bag of cement (based on dry aggregates) an approximation may be obtained of the strength that will result at 28 days. Specimens of concrete mixed in proportions and of consistency suitable for roadwork will generally plot within 500 lbs. of the curve; and the method is therefore seen, in view of the variable results obtained in the compression test itself, to be a fairly satisfactory scheme for estimating strength. For aggregate combinations containing few or no small particles (of such coarse grading as to be unfit for pavement construction), the curve cannot be used. For these aggregates it may be found that the same amount of water per bag of cement is required for a 1:4 mix as for a 1:10 mix, though the latter may test but half as strong as the former.

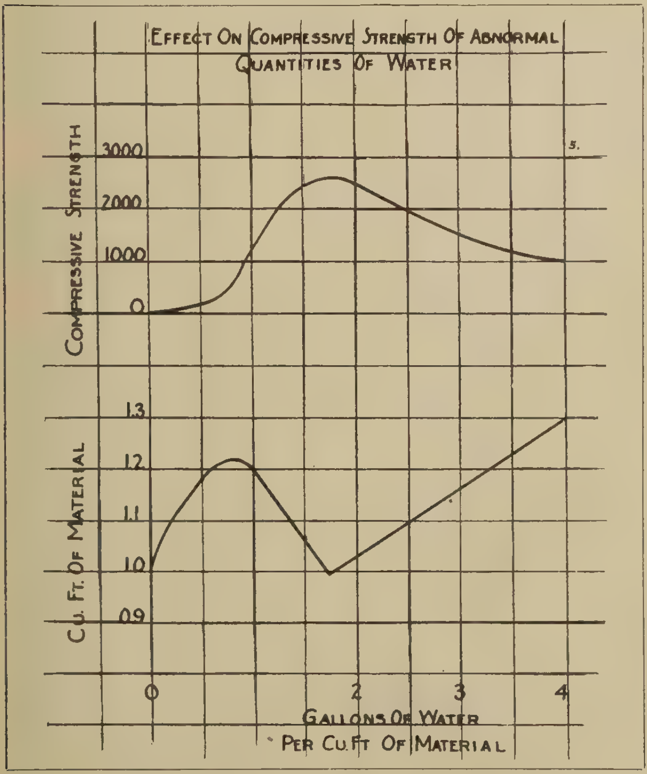


Fig. 5—Comparison of the "Strength" Curve with the "Bulking" Curve of a 1:2:3 Mixture. Maximum Strength Corresponds to Minimum Bulk

When unreasonably dry mixtures are used, the curve is not applicable, which may be explained by reference to Fig. 5, in which the lower curve is a copy of that previously shown as Curve A in Fig. 2. As the amount of water is decreased below 1¾ gals. down to about 1 gal. (for this particular mixture), the concrete is less and less plastic and accordingly the swelling effect is increasing. This leads to excessive voids and thus between 1¾ and 1 gal., decreasing the water is accompanied by decrease in strength; which is the reverse of what is indicated by the water-cement curve, Fig. 5. Further decrease in the amount of water, while not providing sufficient moisture to give maximum bulking effect, also does not provide sufficient moisture for properly molding the specimens, and the strength falls away rapidly to zero.

Using between 1½ and 2 gals. of water per cubic foot of material with the mixture in question gives consistencies close to those generally used for pavement construction, the strength within these limits is fairly uniform, and the maximum corresponds to the point of least volume on the lower curve. When additional water is added it rises to the surface when the concrete is tamped; and further addition, if the concrete is well puddled, simply increases the volume by an amount equal to that of the water added, which is indicated by the straight portion of the lower curve. Strength values obtained with excessively wet mixtures are erratic, results depending upon how the concrete is handled. If all the excessive water is not brought to the surface by puddling, it, being more than required for hydration of the cement, leaves upon evaporation many voids in the concrete. Generally, a good deal of the excessive water is lost in mixing and transporting the concrete; and this wasted water always carries away much valuable cement. While to use more water than necessary to produce a usable consistency wastes cement, reduces strength and should not be countenanced, it should be borne in mind that to use too little water is likewise inexcusable. Too dry concrete is a common fault with base construction from a central plant. Being dry, it dumps readily from trucks, and having more bulk than a wetter mixture, a cubic yard makes more pavement for the contractor.

Referring once more to the water-cement curve, it is desired to emphasize that within its limitations it supplies a direct and easy method of estimating the strength of concrete. Combining with it aggregate measurements on the fineness modulus or other similar lines, merely complicates the procedure and decreases the accuracy of the findings. The number of gallons of water used per bag of cement serves as an index of strength because this ratio measures the cement paste carrying capacities of the different combinations of aggregates. This carrying capacity depends first upon the total volume of voids in the aggregate, and then upon the extent to which this volume is increased when the cement paste is placed around and between the grains comprising the aggregate. With fine aggregates this increase in volume is greater than with coarser ones; and, therefore, for given consistencies, the finer ones require the greater amount of water, the cement paste is diluted to a greater extent, and for given quantities of cement, concretes made with fine aggregates accordingly develop less strength than those made with coarser aggregates.

### Cement Space Ratio

Using the same combinations of aggregates as have just been discussed in relation to the water-cement ratio, but plotting compressive strength against pounds of cement per cu. ft. of space occupied by the cement,

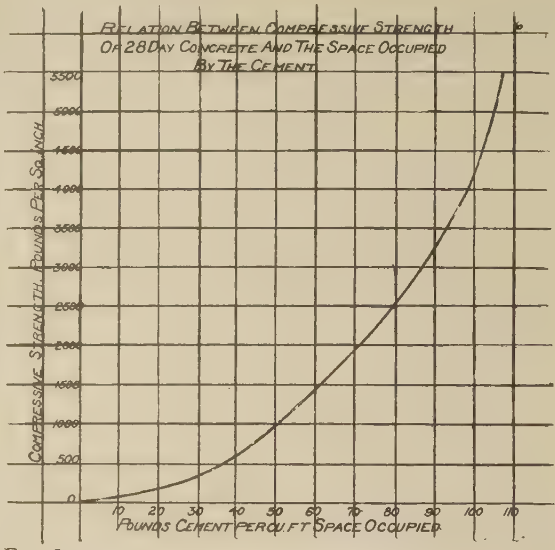


Fig. 6—

a curve was obtained, Fig. 6, differing from a straight line obtained by Professor Talbot, in that the curve begins at zero cement for zero strength and approximates 110 lbs. of cement per cu. ft. of space for neat cement giving a strength of between 7,000 and 8,000 lbs. per sq. in. These are two points neglected by the Talbot straight line. When there is neither time nor facilities for the compression test, this cement-space curve may be used for estimating strength just as the water-cement curve, and with more accuracy, though to figure out the pounds of cement per cubic foot of space is a more laborious matter than to note simply the gallons of water used per bag of cement.

To obtain the cement space ratio it is necessary to know, first of all, the specific gravities of the aggregates. Then, with any proportions, for instance, 1 cement-2 sand-3 gravel, measure sufficient quantities to produce about a cubic foot of concrete. Weigh the sand and the gravel, and, using their specific gravities, compute their absolute volumes. Mix the concrete and puddle it into a measure. Subtracting from the volume of the concrete the absolute volume of the aggregate gives the space which is occupied by the cement paste, from which may be computed the pounds of cement per cubic foot of space occupied.

The cement-space curve holds for dry mixtures (to the point where they can no longer be molded for the compression test) as well as normal ones, because, as the mixtures swell on account of too little water, the space occupied by the cement increases, and therefore decreases in strength caused by insufficient water are fairly well represented. Also in the case of very wet mixtures, where the excess water leads to voids in the concrete, the decreases in strength are taken care of by the increase in space occupied by the cement. When, however, so much water is used that it runs away, carrying cement with it, no scheme can be used for estimating strength, since no one knows how much cement is wasted.

The cement-space curve and also the water-cement curve are general in character and may be applied irrespective of the nature of the aggregates or of the consistency of the concrete. For road work, however, the consistency may be confined to narrow limits and in any one locality there are but few varieties of aggregates available. With these restrictions in mind, it is possible to work out further data, and for these specific cases to show information in greater detail.

### Aggregate Denseness

When a sand is combined with a coarse aggregate in proportions ranging from zero sand with 100 parts of coarse aggregate, to 100 parts of sand with zero coarse, a curve of denseness may be plotted, with, at its vertex, the combination having minimum voidage and maximum weight per cu. ft. Two such curves are shown in Fig. 7. Curve (1) illustrates a 1½ in. gravel combined with a coarse sand, and curve (2) the same gravel combined with a fine sand. These two curves illustrate that, starting with any two aggregates, as, for example, No. 4- 1½ in. gravel and 0-No. 4 sand, certain fundamental rules may be stated:

(a) If fine sand in increasing amounts is substituted for some of the given sand, the peak of the curve moves toward larger and larger proportions of the coarse aggregate.

(b) Substituting coarser sand for some of the 0, No. 4 has an effect the reverse of substituting fine sand.

(c) If fine gravel in increasing amounts is substituted for some of the given gravel, the peak of the curve moves toward larger and larger proportions of sand.

(d) Substituting coarser gravel for some of the No. 4, 1½ in., has an effect the reverse of substituting fine gravel.

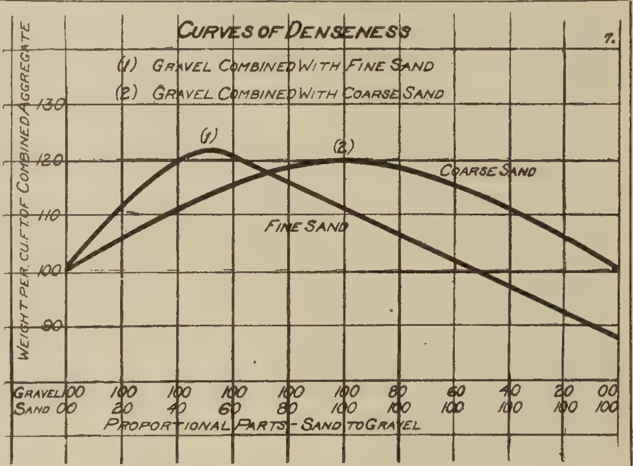


Fig. 7—

It has been held by many that maximum concrete strength is obtained with any given aggregates when they are combined so as to give maximum denseness. A factor in favor of this hypotheis is that, for given proportions of sand and coarse aggregate, more cement is used per cubic foot of combination for the denser mixtures than for those having larger percentages of voids. This may be explained by taking as an example one part cement to four of aggregate; using sand and gravel, each weighing 100 lbs. per cu. ft. If, in the combination, the four parts of aggregate comprise gravel only, the sand being equal to zero, there would be used ¼ bag, or 23.5 lbs. of cement, per cu. ft. of aggregate. If the four parts of aggregate were in the proportion 100 gravel to 100 sand (2:2), and weighed 120 lbs. per cu. ft. as shown by curve (2), Fig. 7, then 120/400 bags, or 28 lbs., of cement per cu. ft. of aggregate would be used.

In opposition to the hypothesis aforementioned, however, there is another factor which, regardless of the denseness, tends to give stronger concrete as the coarseness of the aggregate is increased. The coarser the aggregate the less water necessary for concrete of given consistency, and, accordingly there is less space to be occupied by the cement. Referring to Curve (Fig. 7), a 40 to 100 combination (2:5) has the same denseness as a 100 to 40 combination (5:2), each weighing 111 lbs. per cu. ft. In a 1 cement to 7 of aggregate mixture, 111/700

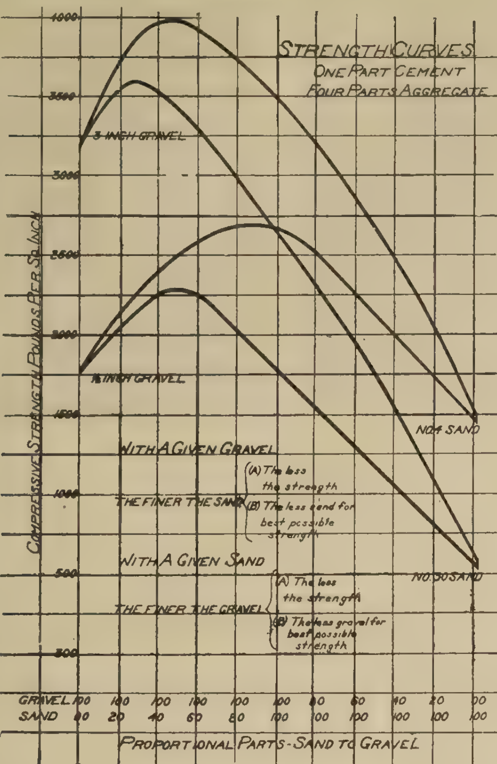


Fig. 8—

bags or 14.9 lbs. of cement would be used per cu. ft. of aggregate, for either the 2:5 or 5:2 combination. Actual trial shows that for the former, based on a consistency suitable for pavements, 1.24 gals. of water are necessary, and for the latter 1.73 gals. per cu. ft. of combined aggregate. The extra water required for the finer aggregate, that is, the 5:2 combination, holds the particles apart and the resulting volume of concrete measures 10% more than that of a 2:5 combination. In the 5:2 concrete the 14.9 lbs. of cement occupies 0.30 cu. ft. of space compared to 0.22 cu. ft. for the 2:5.

The data relative to these two mixtures give for the 2:5 combination 68 lbs. of cement per cu. ft. of space occupied and 7.8 gals. of water per bag of cement; and for the 5:2 combination, 49 lbs. of cement per cu. ft. of space occupied and 10.9 gals. of water per bag of cement. Thus when the strength of concrete is plotted against proportional parts,—sand to gravel, in a manner similar to that used in Fig. 7, the peaks of the resulting curves fall toward larger proportions of gravel than do the peaks of the curves of denseness.

Two factors have thus been brought out, which through controlling the amount of space to be occupied by cement paste, determine the strenth attainable with given amounts of cement. These factors are: aggregate voidage and the extent to which this voidage is increased by the cement paste pushing the aggregate particles apart.

### STRENGTH CURVES

The plotting of strength curves, as illustrated in Fig. 8 (mixtures ranging from straight gravel, through half gravel and half sand, down to straight sand), is the main step necessary in order to understand the basic principles affecting the choice of aggregates for economical concrete. Assuming certain proportions of cement, in this instance, one part of cement to four parts of aggregate, the curves show that coarse sand gives stronger concrete than fine sand, and that the larger the coarse aggregate the stronger the concrete. Having four aggregates, two being coarse and two sand, each coarse aggregate (in this illustration, gravel) may be used with each sand, and therefore there are four curves shown, relative to which the following observations may be made:

(a) The highest curve (maximum strength) represents combinations of coarse gravel and coarse sand.

(b) The lowest curve (minimum strength) represents combinations of fine gravel and fine sand.

(c) The gravel has more influence upon strength than the sand. With either sand, when the coarse gravel is used, a strength above 3,500 lbs. may be obtained, while with the fine gravel, even when using the favorable coarse sand, only a strength approximately 1,000 lbs. below 3,500 can be reached.

(d) Substituting coarse sand for fine moves the peak of the strength curve toward larger proportions of sand; and substituting fine gravel for coarse also moves the peak toward larger proportions of sand. Thus maximum proportions of sand are called for by fine gravel—coarse sand mixtures; and maximum proportions of gravel, by coarse gravel—fine sand mixtures.

Strength curves should be plotted for aggregates peculiar to each locality because dependence cannot be placed upon applying to local aggregates data obtained in investigating foreign aggregates which seem to be similar to the local ones. Difference in grading has a large effect, as for example: a three inch gravel devoid of all material less than two inches will require a larger ratio of sand than if the gravel were graded down to the No. 4 size. The general outline of strength curves depends upon aggregate voidages, upon the shapes and sizes of the individual voids and upon other qualities of the aggregates. Thus a broken stone having the same sieve analysis as a certain gravel will not necessarily be represented by an identical strength curve. In the following paragraphs the practical application of the strength curve fundamentals are illustrated, using as examples, aggregates from the Potomac river.

### THE ECONOMY OF PROPER DESIGN

For many years a 1:3:7 mixture, six inches thick using 1½ inch Potomac river gravel as the coarse aggregate, has been used for concrete base for roadways. In the belief that modern conditions call for a better base, the first thought of many has been that the step to be taken in this direction should be to a 1:3:6 mixture (commonly specified for gravity walls and foundations). For one course roadways, until recently, a 1:2:4 mixture, with 1½ inch gravel was used, then a change was made to 1:2¼-3⅜ (for two reasons: to increase the cement content, and to afford accurate wheel barrow measurement, since local barrows hold 2¼ cu. ft. when struck off level).

The five strength curves, Fig. 9, drawn in full lines, starting with the lower one, represent combinations of 1 part cement to 10, 9, 7, 6 and 5⅝ parts of aggregate respectively; the aggregate being No. 4 sand and 1½ inch gravel. Platted on the curves are the mixtures which have been mentioned, and then in addition two curves (broken lines) are shown based on the use of 4½ inch gravel for combinations of 1 part cement to 7 parts of aggregate and 5⅝ of aggregate. Data pertaining to the various mixtures are shown in the accompanying table. Under the present status of our knowledge of concrete, as used in pavements, it must be assumed that strength is a direct measure of worth. In considering the economy of particular mixtures, strengths in their relation to costs, have to be compared. In the table the costs for materials are net, and therefore in making up the costs of the complete pavement from 5 to 10 per cent

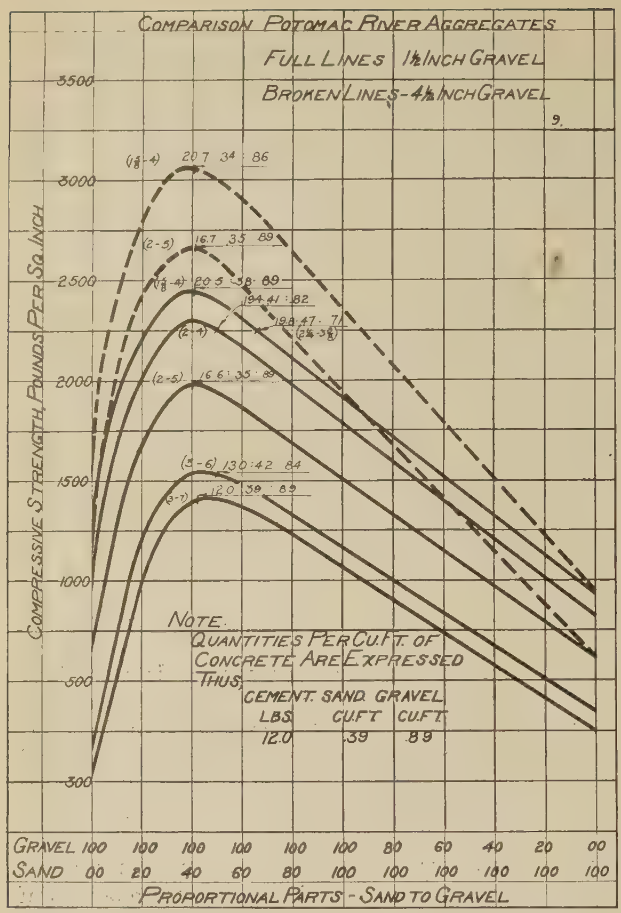


FIG. 9—

should be added to cover waste, the amount depending upon the conditions under which construction is carried on.

| | | Quantities per cu. ft. Concrete | | | Cost per Cu. Ft. of Concrete | | | | 6-In. Pavement, 4½ cu. ft. per Sq. Yd. | | | Percentage Comparison | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Proportion | Size of Gravel | Cement lbs. | Sand cu.ft. | Gravel cu.ft. | Cement at 68c per lb. | Sand at 3.8c per cu.ft. | Gravel at 6c per cu.ft. | Total Cents | Material Per Sq. Yd. | Complete Per Sq. Yd. | Strength of Concrete Lbs. per Sq. In. | Cost | Strength |
| 1:3:7 | 1½ in. | 12.0 | .39 | .89 | 8.1 | 1.5 | 5.4 | 15.0 | $0.67 | $1.53 | 1425 | 100 | 100 |
| 1:3:6 | 1½ in. | 13.0 | .42 | .84 | 8.7 | 1.6 | 5.0 | 15.3 | .69 | 1.57 | 1540 | 103 | 108 |
| 1:2:5 | 1½ in. | 16.6 | .35 | .89 | 11.3 | 1.3 | 5.4 | 18.0 | .81 | 1.70 | 1990 | 111 | 140 |
| 1:2:5 | 4½ in. | 16.7 | .35 | .89 | 11.4 | 1.3 | 5.4 | 18.1 | .81 | 1.70 | 2675 | 111 | 188 |
| 1:2:4 | 1½ in. | 19.0 | .41 | .82 | 12.9 | 1.6 | 4.9 | 19.4 | .87 | 1.88 | 2260 | 100 | 100 |
| 3⅜ | 1½ in. | 19.8 | .47 | .71 | 13.4 | 1.8 | 4.3 | 19.5 | .88 | 1.89 | 2260 | 100 | 100 |
| 1:1⅝:4 | 1½ in. | 20.5 | .33 | .89 | 13.9 | 1.3 | 5.4 | 20.6 | .93 | 1.94 | 2460 | 103 | 109 |
| 1:1⅝:4 | 4½ in. | 20.7 | .34 | .86 | 14.1 | 1.3 | 5.2 | 20.6 | .93 | 1.94 | 3075 | 103 | 136 |

One point to be noted particularly about the 1½ inch gravel mixtures for one course work is that the 1:2¼:3⅜ mixture gives exactly the same strength as a 1:2:4 mixture. If one bag of cement is to be used with 5⅝ cu. ft. of aggregate the best proportion is 1:1⅝:4 at the peak of the curve, giving a strength of 2,460 lbs. per sq. in., a gain of 9% over a 2:4 mixture and at an increased cost of but 2%. With wheel barrow charging of a 4 bag mixer the 1⅝:4 proportion is approximated by 4 bags of cement, 3 barrows of sand and 7 of gravel. Considering the 1½ inch gravel mixtures, for base construction, a change from 1:3:7 to 1:2:5 gives 40% extra strength at but 11% extra cost and is a more worth while change than to 1:3:6 which gives an 8% gain at an extra cost of 3%. With a gain of 40% in strength by changing from a 1:3:7 to a 1:2:5 mixture it is believed that more benefit is obtained than by increasing the thickness of a 1:3:7 base from 6 to 7 inches while the ratio of increased costs is 111% for the former to 117% for the latter. (Whether the concrete base should be made richer, rather than thicker, is a problem requiring much investigation along lines which have thus far been hardly touched by the highway engineer.)

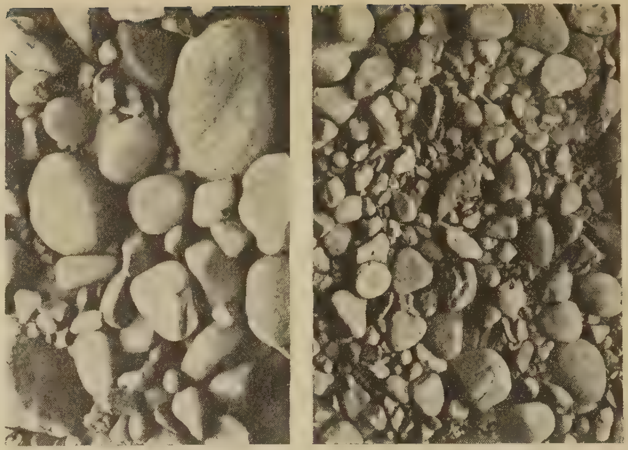


FIG 10—4½ INCH GRAVEL (LEFT) 1½ INCH GRAVEL (RIGHT)

The preceding examples with 1½ inch gravel show plainly the importance of strength curves if a definite knowledge is to be had of the relative values of different mixtures with any one particular aggregate.

Their still greater importance is brought out, however, when attention is given to the curves for the 4½inch gravel. During many years vast quantities, of what is really the best part of Potomac River gravel, have been wasted overboard as tailings from the dredges while 1 inch and 1½ inch products were turned out for roadways and heavy foundations. An exceptionally good sample of 1½ inch gravel is shown in Fig. 10, and yet, simply by retaining larger pieces, thereby obtaining an aggregate such as the 4½ in. gravel shown in the illustration, a concrete is obtained with more than 500 lbs. greater strength than when this 1½ inch sample is used, and the cost not appreciably increased. Four and a half inch gravel, as illustrated, has been used successfully in 6 inch one course pavement in the proportion, 4 bags of cement, 3 barrows of sand and 7 of gravel. (barrows equal 2¼ cu. ft.). This gives a strength of approximately 3,000 lbs. per square inch, which is considered just about right for one course work. For base construction 2,000 lbs. per square inch is believed to be sufficient, in which case it is not necessary to change the old 1:3:7 proportion since with it and using 4½ inch gravel instead of 1½ inch, 2,000 lbs. per square inch may be obtained.

### ESTIMATING CHART

A chart containing a set of Strength Curves together with such data as are shown in Fig. 11 gives a complete history of any chosen aggregates (in the illustration Potomac river 0—No. 4 sand and No. 4—1½ inch gravel). In working up this chart data for each curve should be tabulated somewhat as shown in the accompanying table. For each determination slightly more than a cubic foot of concrete should be made. For each of the three critical proportions, 100/20, 100/40, and 100/60, three determinations should be made; and in each case three 6 x 12 cylinders made for the compression test. If no testing machine is available, entire dependence will have to be placed on the cement-space and cement-water ratios for strengths.

The peaks of the strength curves do not lie vertically one above the other, but what might be called the common diameter of the curves, slopes towards larger proportions of gravel as the mixtures are made richer, evidently the larger quantities of cement permitting a reduction in sand. It is interesting to note, while lean mixtures of straight gravel and cement are not as strong as equal amounts of sand and cement, that richer mixtures with gravel surpass those with sand. For instance, a 1:4 mixture using gravel gives 2,325 pounds per square inch, whereas a 1:4 with sand gives but 1,400 pounds per square inch. With large size coarse aggregates the strength of concrete is approximately that of its mortar. Thus, to a 1:2 mortar giving a strength of 2,750 pounds per square inch, 5 cubic feet of 4½ inch gravel may be added, and the resulting mixture though having a volume several times that of the original mortar will have approximately the same strength, 2,750 pounds per square inch.

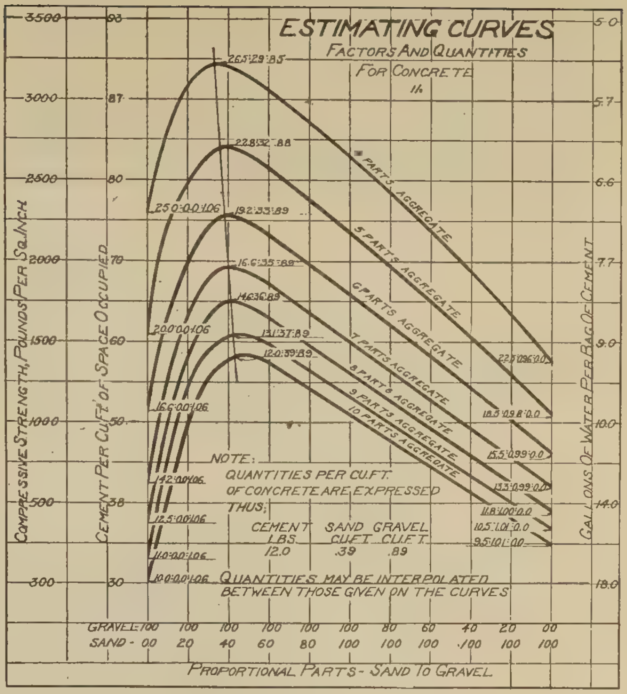


FIG. 11—

### ONE CEMENT TO FOUR AGGREGATE

(SP. GR. OF AGGREGATE = 2.63) (SLUMP, 1½ INCHES)

| A Proportion | B Sand | C Gravel | D Weight | E Cement | F Water | G Water per Bag of Cement | H Absolute Volume of Aggregate | I Volume of Concrete | J Space in Concrete | K Cement per cu. ft. of Space | L Strength |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Measured | Measured | Weighed | $\frac{94\text{x}1.2}{4}$ | Meas'red | $\frac{94\text{x}F}{E}$ | $\frac{D}{}$ | Measured | I-H | $\frac{E}{J}$ | Test |
| | cu. ft. | cu. ft. | lbs. | lbs. | gals. | gals. | cu. ft. | cu. ft. | cu. ft. | lbs. | lbs. sq. in. |
| $\frac{100}{20}$ ...... | 0.2 | 1.0 | 120 | 28.2 | 1.59 | 5.3 | .073 | 1.088 | .358 | 78.3 | 3100 |
| $\frac{100}{40}$ ...... | 0.343 | 0.857 | 120 | 28.2 | 1.66 | 5.55 | 0.73 | 1.080 | .350 | 80.0 | 3225 |
| $\frac{100}{60}$ ...... | 0.45 | 0.75 | 120 | 28.2 | 1.68 | 5.6 | 0.73 | 1.091 | .361 | 78.0 | 3075 |

In plotting curves it is worth noting that when the consistency of the concrete is maintained constant (in the present instance, a consistency suitable for pavements), and the aggregates are not changed, nor the ratio of sand to coarse aggregate; then the addition of each 1 per cent of cement for lean mixtures, increases the strength of the concrete by approximately 1 per cent. Thus, assuming for example, 40 parts of sand to 100 of gravel, a 1 cement to 9 of aggregate mixture has 10/9 the strength of a 1 cement to 10 of aggregate mixture, therefore if the latter is 1,400 lbs. per square inch the former is about 1,550 lbs. per square inch. A 1:7 mixture has 10/7 the strength of a 1:10, and is therefore about 2,000 lbs. per square inch. As the mixtures are made richer and richer, the 1% rule fails rapidly, thus, a 1:4 mixture is not quite twice as strong as a 1:8 and a 1:2 mixture has far from 200% of the 1:4 strength; because the limit of strength is that of neat cement which may be no more than 7 or 8 thousand pounds per square inch.

For lean mixtures a 1% increase in cement gives close to 1% increase in pounds of cement per cubic foot of concrete. As the quantity of cement is increased, a bulking effect takes place. For example, a quarter bag of cement may be mixed with 1 cubic foot of aggregate and give less than a cubic foot of concrete. If the cement is increased to 400%, that is to one bag, and mixed with 1 cubic foot of aggregate, much more than one cubic foot of concrete will be obtained, and therefore the increase to 400% cement does not give an equal increase in pounds of cement per cubic foot of concrete, this latter being not much more than 200%.

### PROPORTIONING BY THE USE OF TABLES

The accurate way to know one's concrete with its elements such as strength, quantities of material, etc., is through investigation such as has been outlined in preceding paragraphs. Concrete is about .7 of the volume of the sum of the aggregate and cement volumes. When the aggregates consist of relatively large particles, the factor is somewhat smaller, and when the aggregates are finer the factor is somewhat larger but for aggregates common to most pavement work a factor of .7 gives a good working rule of thumb. Thus, for example, one bag of cement, two cu. ft. of sand, and four of gravel may be assumed to give 0.7 x 7 or 4.9 cu. ft. of concrete, one bag of cement and two cu ft. of sand, to give 0.7 x 3 or 2.1 cu. ft. of mortar.

For many years in the past, Taylor and Thompson's tables of quantities have been used for estimating purposes; but they have one shortcoming in that they give no idea of the strength that may be expected from the use of given proportions.

Bulletin No. 9, Structural Materials Research Laboratory, Lewis Institute, Chicago, contains tables for "Proportions and Quantities of Materials for Concrete of a Given Compressive Strength." Portions of these tables are included in the 1921 Joint Committee Report, in order to furnish a guide in determining the proportions of materials required to produce a concrete of given strength.

# Reinforced Concrete Bath House Withstands Sulfur Vapors

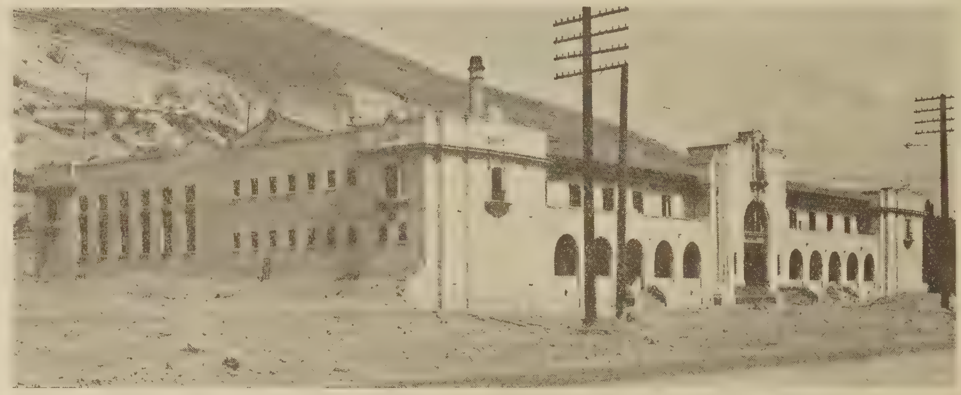


FIG. 1 — SALT LAKE CITY'S NEW MUNICIPAL WARM SPRINGS BATH HOUSE

In deciding upon the type of construction for the new municipal bath house at Salt Lake City, the designers of the structure were influenced by experience with a bath house in the same locality constructed of wood many years ago, in which the pools had been rebuilt with concrete and concrete had been found to be the only material to resist the disintegrating action of the vapor from the sulfur water of the springs. The additional reason that excellent concrete materials were abundant only a short distance from the site, and concrete construction was well suited to the type of building to be erected also helped in making the decision.

The structure houses a large swimming pool, a medium sized pool for private parties, seven small pools for individual use, and the complete equipment for bathing and swimming.

Near the present site of the new baths a bath house of wood construction was erected a number of years ago. In later years, when cement concrete had come into general use, the pools in the old bath house were rebuilt, using concrete. It was found that the concrete had the quality to withstand the action of the hot sulfur water while other portions of the building showed deteriorating effects. The wooden roof trusses became saturated and waterlogged, requiring frequent attention and repair to keep them same, and the iron work was subjected to corrosion unless it was heavily galvanized. Galvanized iron pipe seemed to resist the action of the vapor, but other iron, even cast iron of the radiators, was rapidly corroded.

In the new building concrete was used for footings, foundations, walls, main roof trusses, roof slabs, floors and steps. In a few cases hollow terra cotta tile were used for minor partitions and these were plastered with cement. No steel was used other than for reinforcing the concrete. The steel is so embedded that it will not be affected by the vapor. Galvanized steel sash windows were used exclusively in the different pool rooms, and the steel was heavily coated to protect it from the action of the vapor. Doors in the walls surrounding the pool rooms were of steel, with steel frames heavily protected with burnt-on enamel. Experience with the old bath house showed that disintegrating action was most in evidence in the pool rooms, where there was excessive vapor. The equipment in the rooms remote from the pools seemed to stand up quite normally, so wooden doors and windows were used in the new building for the accessory rooms.

The roof above the main pool room was the chief problem of construction, and as wood and steel were both out of the question, trusses were designed and built of reinforced concrete, being designed as 3-hinged arches. Seven such arches support the main roof, and the bases of the arch piers were secured by horizontal steel tension rods placed below the pools, and carefully concreted in.

In the roof slab above the large pool, a number of skylights were introduced to furnish the additional light needed. These lights are of the so-called sidewalk light type, of prism glass set in reinforced concrete slabs.

The roof slab above both the large and the medium sized pools was insulated by means of a 1-in. layer of insulating felt, applied to the top surface of the concrete slab in a mopping of hot pitch. Over this was applied the finished built-up composition roofing. The object of the insulation is to prevent or retard as far as

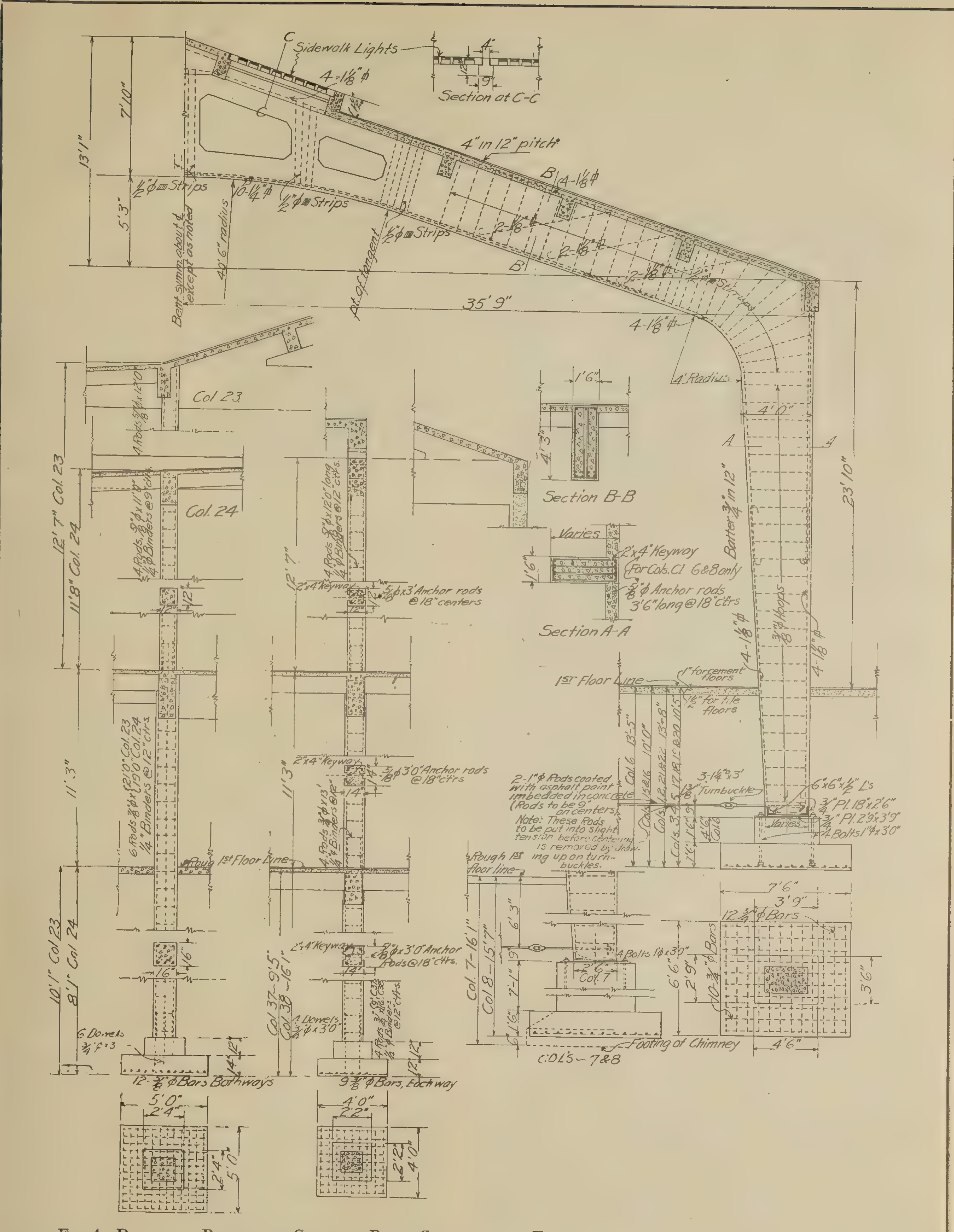


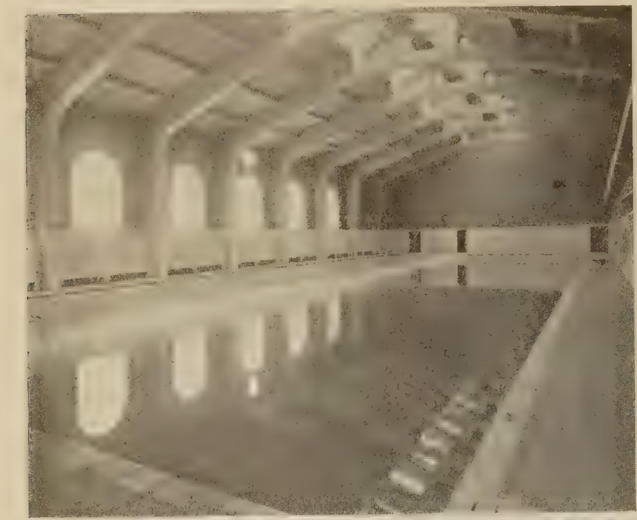
Fig. 4—Details of Reinforced Concrete Bent, Columns, and Footings

possible the loss of heat through the roof, and also to prevent the condensation of vapor from the pools on the underside of the roof structure.

The shells of the two pools are constructed of reinforced concrete, with enameled brick walls and 4-in. cement floors, with a built-up waterproofing membrane in between. The pool gutters, ladders and steps are of glazed terra cotta.

### Construction Methods

In carrying out the construction program, the general contractors set up a steel mast with 100 ft. boom, carrying a bucket of 2 cu. yds. capacity, in the center of the main pool room, which was approximately in the center of the building. The mixing plant was arranged in the rear of the building, in such relation to the hoisting equipment that the swinging boom could handle the concrete, taking it directly from the mixing plant and conveying it to any part of the building where it was to be placed with minimum time and labor. As the building neared completion, the mast and boom were removed through the one panel which had been left open, the remainder of the work being done by hand labor.



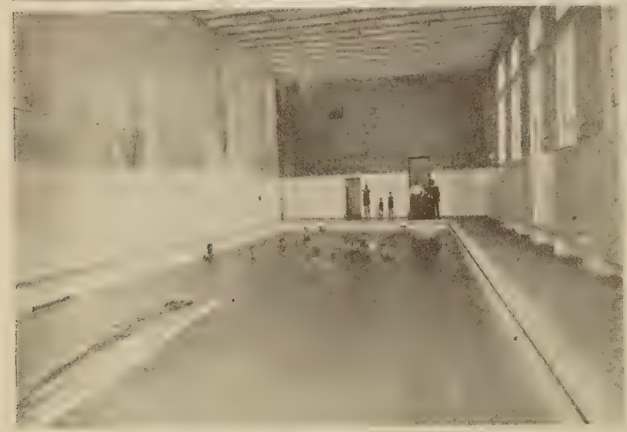


Fig. 2—Interior of Bath House, Showing Large Pool with Concrete Roof Trusses

Fig. 3—Interior of Medium Pool Room

The hot water supplying the pools is brought into the building in cement conduits, and the run-off from the pools is handled in a similar manner. All inlet valves and outlet gates, including the overflow strainers in the pool gutters, are of bronze, as this metal also has proved invulnerable to the attack of the water and its vapor.

The steam radiators installed in the pool rooms have been heavily galvanized and are protected so that no swimmer can possibly be burned by coming in contact with the steam radiators.

### The Main Pool

The main pool is 120 ft. long and 50 ft. wide. The depth is from 3 to 7 ft., starting with 3 ft. at the southern end and deepening to 7 ft. at the northern end. The walls of the pool room have panels of tile 7 ft. high.

The architects who designed the bath house are Cannon & Fetzer, Salt Lake City, and construction work was carried out by the Lynch-Cannon Engineering Co. Much credit for the work in making the bath house possible is due Commissioner Herman H. Green. It is estimated that the attendance of the new bath house can be brought up to 320,000 per year, and at this rate the entire indebtedness for the structure, costing approximately $330,000, can be paid within the next six years.

## Inundation Method for Sand Measurement and Water Control

The reliability of concrete construction is likely to be increased, and the cost in some cases reduced, by the application of a newly developed method of measuring sand, which is now being tested at the Bureau of Standards of the Department of Commerce. The method has been termed the "inundation method, and consists of measuring sand in a container which has been partly filled with water before the sand is put in, so that when the sand is in, the water is up to the top and the sand completely soaked.

The volume occupied by a given amount of sand when shoveled into a measuring device varies with the moisture content of the sand; the difference in measured volume between dry and moist sand being usually from 10 to 15 per cent and occasionally running as high as 50 per cent. But it is found that if the sand is completely soaked or "inundated" uniform measuring results can be obtained no matter how much the original moisture content may have varied.

In making concrete the proportions of cement, sand, stone, and water are so chosen as to get the required strength and workability with a minimum of cement, since the cement is the chief factor in the cost. Inaccurate measurement of the sand may result in too large a proportion of sand, in which case the concrete is too weak; or in too small a proportion of sand and hence a concrete too rich in cement.

But this rich concrete is not necessarily stronger than the concrete the contractor intended to make, for the sand has brought in some water in addition to that which is added on purpose; and if this extra water is not allowed for and the amount of water added correspondingly decreased the concrete will contain too much water. It will be slipping and when set will not be dense enough to give the necessary strength. The contractor therefore is merely wasting cement and doing good to no one.

It is hoped that with the inundation method it may be possible to specify concrete by the strength required rather than by arbitrary proportions. The contractor can then find the proportions of the materials he is using that will give the requisite strength and can adhere closely to these proportions. The result will be a concrete whose proportions are more nearly what they were intended to be, and with which a lower factor of safety can be used. (This is to be the subject of a paper and demonstration at the American Concrete Institute Convention in Cincinnati, January 22-25.)

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Such a stimulating effect was produced by the American Building Exposition held in Cleveland in May, 1922, that another show will be held April 4-14, 1923, at the Municipal Auditorium. It is under the direction of the Better Homes Exposition, R. G. Collier, manager, 1307 Schofield Building, Cleveland.

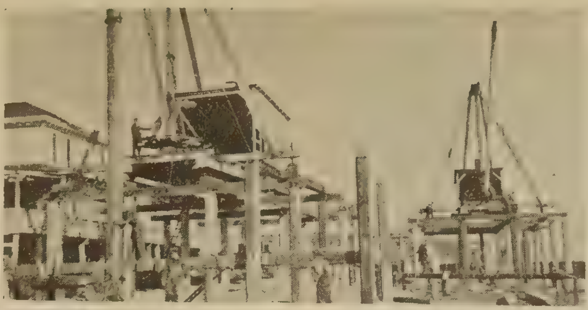


FIG. 1—SINKING CONCRETE PILES BY WATER JET

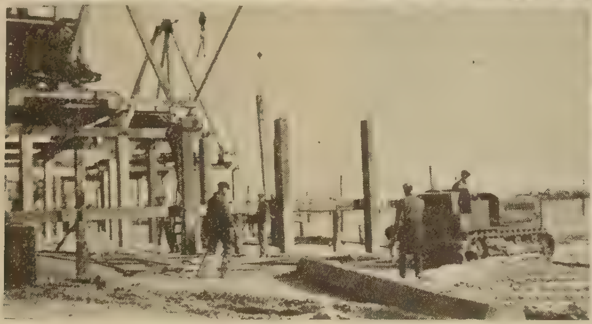


FIG. 2—HAULING CONCRETE PILES BY TRACTOR

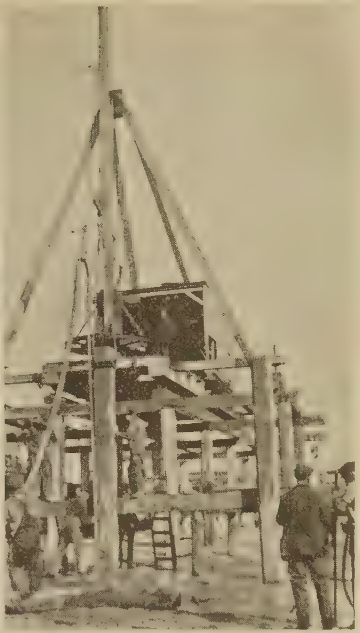


FIG. 3 — (RIGHT) SINKING CONCRETE PILES BY WATER JET

# Coney's Board Walk Supported on Concrete Piles

The main structure of the Coney Island Board Walk, located at West Thirty-seventh Street, extending from the foot of Ocean Parkway to the entrance of Sea Gate, a distance of approximately 9,500 ft., consists of reinforced concrete girders built in place on top of precast concrete piles, transported to the site of the structure and jetted down to the required depth, as shown in the accompanying illustrations. The piles are arranged in bents 20 ft. apart, and containing 8 piles each.

The piles are 14 in. square and 28 ft. long. The seasoned piles were transported by barge from the yard where they were cast to the site of the work, and hauled to the place where they were to be used with the aid of a tractor. After being jetted to the approximate grade, they were driven the rest of the way with a piledriver. Two derricks were used and the structure was built in two longitudinal sections. One of the outstanding features of the foundation structure is the exact alignment in which the piles were kept in jetting and driving.

Each group of four piles is topped by a reinforced concrete girder approximately 39½ ft. long, 10 in. wide and 22 in. deep. The ends of the girders cantilever beyond the piles to support an additional width of the board walk. A longitudinal expansion joint has been provided

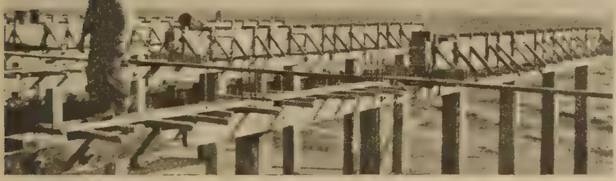
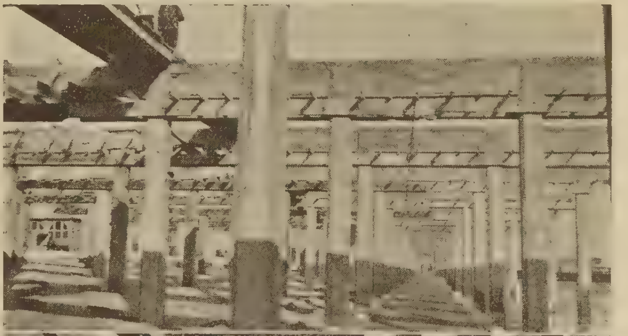
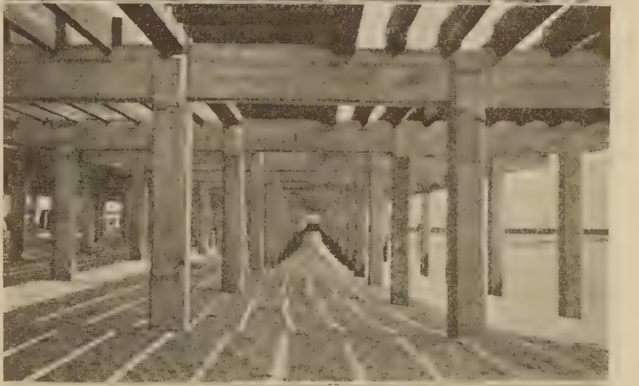


FIG. 4—FORMS IN PLACE FOR CONCRETE GIRDERS ON CONCRETE PILES





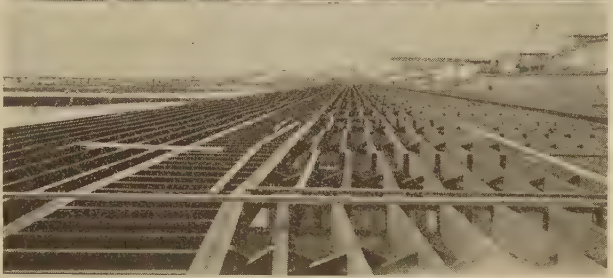
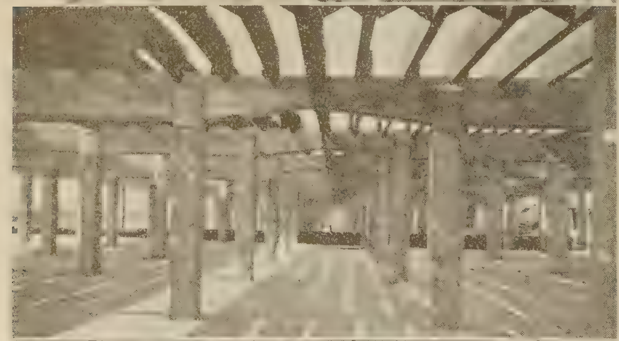
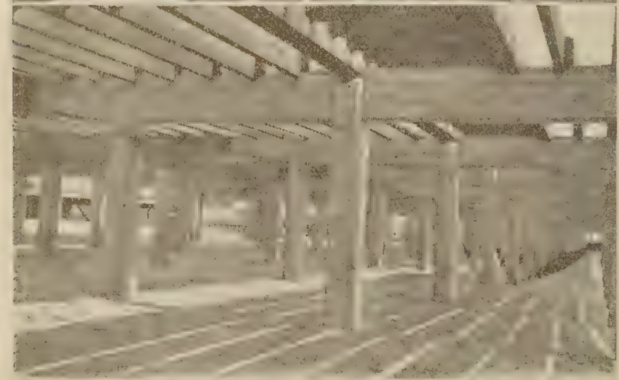


FIG. 5—CONCRETE GIRDERS IN FORMS AND STRIPPED, WITH CONCRETE CARRY-ALL SHOWN ABOVE

FIG. 6—CONCRETE PILES AND GIRDERS, WITH WOODEN FLOOR BEAMS IN PLACE

FIG. 7—WOODEN FLOOR BEAMS IN PLACE BEFORE PLANKING—NARROW STRIP FOR LONGITUDINAL PLANKING FOR WHEEL CHAIRS





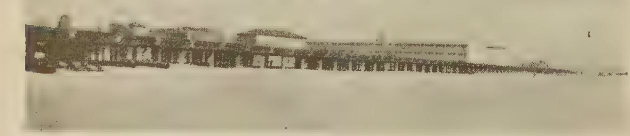


Fig. 8—Planking for Wheel Chairs in Place—Main Flooring Under Construction—Concrete Municipal Baths in Background

Fig. 9—Showing Two Girders in 80 ft. Width of Walk

Fig. 10—View Under Center of Structure—Showing One of Timber and Stone Breakwaters Built About 800 ft. into Ocean, Between Which the Beach Is Being Filled by Hydraulic Dredge

Fig. 11—Concrete Piles and Girders, Showing Normal Head Room After Filling in of Beach Is Completed

Fig. 12—General View Toward East—Concrete Municipal Baths in Right Foreground—Showing Section of Filled-in Beach

Fig. 13—General View Looking West—Showing Section Between Bulkheads or Breakwaters Not Yet Filled in

down the middle of the structure, dividing it so that each bent is composed of a group of four piles, instead of eight. The piles were sunk to such a depth that when the sand fill is placed beneath the board walk, they will extend about 20 ft. into the sand. The finished floor will be 13 ft. above normal high tide and will be reached by double ramps at street intersections. A live load of 125 lbs. per sq. in. was designed for.

Forms for the main girders were supported on temporary timber beams placed on either side of the piles and bolted together. A 1:1½:3 mixture was used, the coarse aggregate being trap rock, with outside size of 1 in. All steel reinforcing is embedded 3 in. to insure against action of sea water. Additional protection is provided on the piles and girders by a cement finish coat. The concrete was mixed on shore and conveyed to the forms in buggies running on staging built over the forms.

In order to avoid handling materials, equipment and form work over the concrete before it had become properly hardened, and the side forms stripped, pouring was done in the opposite direction to that of construction of the pile bents.

The board walk was designed by Philip P. Farley, Brooklyn, N. Y., and constructed under his special direction, through the Bureau of Highways, with J. F. Schmitt, chief engineer.

# Useless Metal Lath Weights Eliminated

Reduction from more than 80 varieties to 10 of expanded flat metal lath, and from more than 70 to 7 in ⅜ in. expanded rib lath now being used extensively in the building industry, was recommended recently at a conference of metal lath manufacturers, users and distributors held at the Department of Commerce under the auspices of the Division of Simplified Practice.

The results of a survey of the excess and useless weights of metal lath, made by the Metal Lath Manufacturers' Association, were used as a basis for eliminations and retention. The adoption of the following recognized standards of weight in this commodity during the year July 1, 1923, to July 1, 1924, was recommended by the conference:

| | Flat Expanded Lath | |
|---|---|---|
| Painted Steel | Special Metal | Galvanized Before |
| 2.2 | 2.2 | ... |
| 2.5* | 2.5* | 2.5 |
| 3.0* | 3.0* | ... |
| 3.4 | 3.4 | 3.4 |
| | ⅜-in. Rib Expanded Lath | |
| 2.5 | ... | ... |
| 3.0* | 3.0* | ... |
| 3.8* | 3.8* | ... |
| 4.8 | 4.8 | ... |

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*The conference urged that every effort be made in the industry to direct practice to a consolidation of the two starred sizes to a single intermediate weight. This to be made effective, if possible, at the next conference.

Tolerance to be not greater than plus or minus 0.1 lb. per sq. yd.

The conferees are of unanimous agreement that adoption of the recommended standard weights, which will amply supply the needs of construction, by the industry as a whole, will result in the greatest benefit to manufacturers, distributors and users of the article affected.

# Stave Silo Men Talk Better Business

The Seventh Annual Meeting of the National Concrete Stave Silo Association was held at the Sherman Hotel, December 5, 6, and 7, and undoubtedly was the most successful in the history of the organization. Approximately 80 manufacturers were registered. The program was especially strong and each talk was followed by spirited discussions.

A talk by Mr. Grabill on the subject, "Who Is My Competitor?" was a whole program in itself. He proved conclusively that the silo manufacturers' competitors were not the other silo manufacturers, but were the manufacturers of automobiles and luxuries. He quoted figures showing that the biggest year in the farm implement industry, including all farm implements, was the year 1919, when, in round numbers, $324,000,000 worth of farm machinery and equipment was produced. This year Henry Ford sold over $800,000,000 worth of Fords, and $540,000,000 of it to the American farmer. He further explained that the farmer was buying radio outfits, phonographs and other non-essentials, instead of investing in farm machinery and silos. The farmers' attitude was also given as one of the silo manufacturers' most obstinate competitors. The plain lesson was the necessity for more advertising and other salesmanship.

This line of thought was developed also by the address of A. J. R. Curtis, manager of the Cement Products Bureau of the Portland Cement Association. He briefly reviewed the present silo situation and opened the eyes of the silo manufacturers to the fact that silos are not getting the publicity which they formerly did. The experimental stations, extension departments and county agents are regarding the silo as a closed proposition, and in the last few years have done practically nothing to promote and advocate the use of silage; consequently, the interest of farmers in the economic value of silage is gradually dying out. A remedy to this serious situation was proposed in the form of a big national silo conference, to be held some time the latter part of February or early in March, invitations to this conference to be extended to all silo manufacturers regardless of type, to manufacturers of silo accessories and silage cutter machines, farm newspaper editors, county agents, college men and all others directly or indirectly interested in silage. The stave manufacturers voted unanimously in favor of such a conference and selected a committee consisting of K. J. T. Ekblaw, C. C. Woody and M. B. Fry, to arrange the details.

Mr. Curtis' talk was followed by a lecture by K. J. T. Ekblaw, telling what the Portland Cement Association had done during the past year in helping manufacturers to sell silos, and he also laid special emphasis on the need for a silo conference to awaken silo interest in general. Mr. Ekblaw's lecture was discussed by A. L. Haecker, of Lincoln, Neb., who further stressed the need for silo publicity and explained his work during the past year.

H. Hayward, head of the agricultural division of N. W. Ayer & Son, Chicago, gave a rousing talk on the need for silos, and proposed a national silo campaign. While the general concensus of opinion was that such a campaign would be desirable and beneficial, it was not possible to undertake such action at present.

A paper on "Concrete Stave Specifications and Recommended Practice for Their Manufacture," was prescribed by W. G. Kaiser, secretary of the organization. He proposed specifications requiring staves to meet certain tests as to transverse strength, compression and absorption, based on tests made at the Structural Materials Research Laboratory, Lewis Institute, and tests made by the Minnesota Cement Construction Co., and the Michigan Silo Co. It was decided to send these specifications out to all members and have a ballot vote regarding whether they should be adopted or not. It was felt that the specifications should be studied very thoroughly before taking final action.

M. B. Fry of Neff and Fry, Camden, Ohio, gave one of the best talks on concrete stave coal pockets that was ever heard at a silo association meeting. He has enjoyed a very successful year, having completed 104 coal pockets and five aggregate storage bins.

Branching out in the concrete stave business was a subject that occupied the balance of the forenoon session. There was a great deal of interest among manufacturers in this subject because they have felt that there is a need to take on some other products in order to cut down overhead costs during seasons when the silo business is not brisk. C. L. Douthett, Waterloo, Iowa, led the discussion on corn cribs, trimstone, burial vaults and some of the other products that are being made in his plant. This subject was discussed further by B. F. Gurney of Winona, Minn., and by M. B. Fry of Camden, Ohio, and by others.

The address on "The Economic Situation," given by B. H. Hibbard, head of the Economics Department, University of Wisconsin, received a hearty response. In the plainest kind of language Professor Hibbard explained why the farmers are having such financial difficulties at present. Frank I. Mann, known throughout the country as an expert on soil fertility problems, gave a talk on the subject "The Silo as a Factor in Maintaining Soil Fertility." Mr. Mann has a farm at Gilman, Ill. and knows the farmers' viewpoint. He showed how livestock was essential in keeping our farms at top notch production and that a silo was a necessity in producing livestock economically.

Stave silo manufacturers in many sections have long felt that they are not getting just an equitable fire and storm insurance on their silos, the rates in some sections being the same as on wood silos and other less permanent types. The subject of silo insurance was well presented by I. D. Goss, Manager of the Farm Department of the Continental Fire Insurance Co., and it was pretty evident from the discussions that followed that concrete stave silos should be given better rates. Although many manufacturers consider that it is not necessary to carry insurance on concrete stave silos, it sometimes happens that a farmer will want insurance and when he finds that the rates are the same as on wood silos he naturally feels that he is not being justly treated. During the coming year the Silo Association will work with the insurance companies in an effort to work out a solution for this problem. The meeting adjourned at noon on December 7 after holding a roundtable discussion on matters of special interest to stave manufacturers.

W. B. Trost, of the Waterloo Concrete Corporation, was elected president for 1923; M. B. Fry, of Neff & Fry, Camden, Ohio, vice-president, and W. G. Kaiser was re-elected secretary-treasurer.

# Institute Convention Offers Practical Program

The convention of the American Concrete Institute to be held in Cincinnati at the Sinton Hotel Monday to Thursday inclusive, January 22-25, 1923, offers a very full program which includes the practical problems of the concrete contractor and the products manufacturer in liberal measure, the artistic side of concrete and the matters of research, testing and design theories, no less important. The program is announced in detail in the Institute *News Letter of* December 22 which also announces reduced railway fares to Cincinnati for the meetings. A summarization of the program outlined is as follows:

Jan. 22, 2 p. m.: Concrete Products Manufacture—"Modern Methods in Making and Laying Concrete Pressure Pipe," with moving pictures and stereopticon, by W. G. Chase, Lock-joint Pipe Co., Ampere, N. J.; presentation of "Proposed Standard Specifications for Concrete Building Block and Concrete Building Tile," and "Proposed Standard Specifications for Concrete Brick," by W. R. Harris, Chairman Committee P-1; presentation of "Proposed Tentative Standard Specifications for Concrete Staves," by Walter Brassert, Chairman Committee P-4; Results of Fire Tests of Concrete Building Block, by Leslie H. Allen, Chairman Committee P-5; discussion "Design of Reinforced Concrete Pipe," led by C. F. Buente, Chairman Committee P-7.

8 p. m.: Roads—A moving picture discussion of "Modern Methods in Concrete Road Building," G. A. Sherron at the crank, Koehring Company, Milwaukee, Wis.; "Design and Construction Features of the Ideal Section of the Lincoln Highway—and Why," by W. G. Thompson, consulting engineer, St. Petersburg, Fla.; "The Trend of Design and Construction of Concrete Roads," by H. Eltinge Breed, consulting engineer, New York City; "Correction Data for Comparative Test Results from Field Specimens," by G. W. Hutchinson, assistant engineer, North Carolina State Highway Commission, Raleigh, N. C.; Progress Report Toward Standard Specifications for Concrete Culvert Pipe, by B. S. Pease, Chairman Committee J-2; presentation of "Proposed Revised Standard Specifications for One Course Concrete Highway," by W. M. Acheson, Chairman Committee S-6.

Jan. 23, 9:30 a. m.—Concrete Products Manufacture: Discussion and Demonstration of the Application of Scientific Methods of Making Concrete to the Requirements of Concrete Products Manufacturers—with Dollars and Cents Reasons Therefor, by Prof. Duff A. Abrams and Stanton Walker, Structural Materials Research Laboratory, Chicago; "How to Make More Money in Concrete Building Unit Manufacture," the report of Committee P-6, John Lowell, Chairman, followed by Round Table discussion of Products Plant Operating and Cost Problems.

2 p. m.—Report of Board of Direction, Reviewing Institute Affairs of the Year, by the Secretary; 20 minute discussion, "For the Good of the Organization," led by President W. P. Anderson; "Effect of Impure Water on the Strength of Concrete," by Prof. Duff A. Abrams, Structural Materials Research Laboratory, Lewis Institute, Chicago; "Design of Elastic Structures from Paper Models," by Prof. George E. Beggs, Princeton University; Progress of the Work of the Joint Committee on Concrete and Reinforced Concrete, by S. C. Hollister, Chairman Institute Representation; Research in the Field of Concrete, by W. K. Hatt, Chairman Committee E-3; Defining the Special Terms Peculiar to Concrete Work, Report of Committee G-4, Nomenclature (preprinted), by W. A. Slater, Chairman; "The Aims and Purposes of the Hampton Builders' Course," by H. Whittemore Brown, Hampton Normal and Agricultural Institute, Hampton, Virginia; "An Interesting Case of Dangerous Aggregate," by J. C. Pearson, Chief Cement Section, United States Bureau of Standards, and G. F. Laughlin, U. S. Geological Survey.

8 p. m.—House Construction and Architectural Concrete: "Thoughts on Concrete Houses," by J. C. Pearson, Chief Cement Section, United States Bureau of Standards; "The Fountain of Time and a New Technique in Concrete"; "Developments in Surface Treated Concrete and a Demonstration of Mold Making, Casting and Surface Finishing Methods in Ornamental Work," by R. F. Havlik, Mooseheart, Ill.; Presentation of "Proposed Revised Standard Recommended Practice for Portland Cement Stucco," by J. C. Pearson, Chairman Committee C-3; Presentation of "Proposed Standard Specifications for the Finish of Exterior Surfaces of Concrete Industrial Buildings," by J. C. Pearson, Chairman Committee C-3.

Jan. 24, 9:30 a. m.—Stadiums: "Design, Construction and Cost of Concrete Stadiums," by Prof. Clyde T. Morris, Ohio State University, Columbus, with discussion by Prof. C. C. Williams, University of Illinois Stadium; H. T. Campion, University of Pennsylvania Stadium; and R. L. Bertin, New York Yankees' Stadium; report of tellers and induction of officers.

2 p. m.—The opening of the Question Box for Engineers and Contractors. Final program will list ten or twelve questions and the names of those assigned to discuss them. Report of Committee C-1—Contractors' Plant, by J. G. Ahlers, Chairman; presentation of "Proposed Standard Specifications for Concrete Floors" (preprinted), by N. M. Loney, Chairman Committee C-2; presentation of "Proposed Standard Specifications for Concrete Fuel Oil Storage Tanks" (preprinted), by G. A. Smith, Chairman Committee S-4; presentation of "Proposed Standard Specifications for Concrete Sewers" (preprinted), by Langdon Pearse, Chairman Committee S-3; "A New Design for Concrete Water Tanks," by William S. Hewett.

8:30 p. m.—A Get-together Evening, with light refreshments; Moving Pictures—"Built to Endure," a building construction film, George Sherron of the Koehring Company at the crank; presentation of Wason medal by Frank Wight, Chairman Wason Medal Committee; other features of special and informal entertainment.

Jan. 25, 9:30 a. m.—Good Concrete: "Some Defects in Concrete Buildings—Their Causes and How to Minimize by Proper Design," by H. D. Loring, Ferro Concrete Construction Co., Cincinnati, O.; "Inundation Methods for Measurement of Sand in Making Concrete," by W. A. Slater and G. A. Smith, United States Bureau of Standards; discussion and practical demonstration of Inundated Sand Method of Water Control, by R. L. Bertin; report of Committee E-7—Waterproofing, by S. C. Hollister, Chairman.

2 p. m.—Good Concrete: An Analysis of the Variables in Concrete from the Construction Standpoint, with Some Results of Job Tests, by W. P. Bloecher, Stone & Webster, Inc., New York, N. Y.; Causes of Steel Corrosion and Concrete Disintegration and Methods of Their Prevention, by M. M. Upson, Chairman Committee E-6; report of Field Tests of Methods used in New York Building Construction for obtaining Concrete of Specified Strength, by J. G. Ahlers.

Arrangements have been made for reduced railway fare for members provided 250 "certificates" are presented at the convention. When buying their going tickets members should get certificates which will entitle them to half fare on return trip if 250 "certificates" are collected at the convention.

# How to Polish a Concrete Surface

A reader of *Concrete and Constructional Engineering*, (England) asks how a concrete surface may be polished, to which the editor's reply is:

"In order to polish concrete like marble or granite the surface will have to be rubbed down as in terrazzo work. A semi-polish can, however, be obtained as follows, supposing the surface to be reasonably smooth:—Dissolve ¼ lb. potassium carbonate in one quart of boiling water, and, whilst boiling, add and stir until dissolved, ¼ lb. of beeswax in slices; or melt the wax and add to the hot water and potassium carbonate mixture. If too thick, add enough hot water to make it creamy when cold. Apply with a brush or rag, let it dry or partially dry, and polish with a stiff brush."

# Ciment Fondu or Alcement

## *Translation of a Lecture by Rud. Christiani, M. Ing. F., in Danish Engineering Society*[1]

By E. Lee Heidenreich

Since the visit of the scientist, Henry le Chatellier in Copenhagen, about a year ago, when he suggested a closer examination of the new quick hardening cement, Ciment Fondu, which in his opinion is to become of great importance in reinforced concrete construction, we have gone more thoroughly into the matter and the results of our investigations form the basis for the following:

To enable one to form comparisons with the preparation, as well as the qualities of the new material, I shall briefly touch upon the principal points of interest in the make and use of the usual binding mortars and refer further to Professor Suenson's treatise on both the production and use of lime and cement mortars.

According to the temperature of the burning, these materials may be divided into two groups:

(A) Raw materials burnt at low temperature, about 900° C.

(B) Raw materials burnt to calcination and fusion up to 1500° C.

The first ones are principally lime, hydraulic lime and Roman cement. Here the lime does not contain any appreciable amount of clay, while the hydraulic lime contains only enough to permit it to be slaked, and the Roman cement so much clay that it cannot be slaked, but must be pulverized by grinding before it can be used. Burning the limestone eliminates the carbonic acid by splitting the carbonate of lime into calcium oxide and carbonic acid, which escapes.

By the slaking of the burned lime this is changed into hydrate of lime, which, exposed to the influence of air, hardens in forming carbonate of lime.

The burned lime, containing clay (hydraulic lime or Roman cement), will in burning lose some silicic acid, which in the hardening so combines with the hydrate of lime that the hardening not only consists of the formation of *calcium carbonate*, but a *calcium silicate* is formed as well.

In the meanwhile, this really is not all of it; aluminates are formed, and no one really *knows* what happens during the hardening of mortars, or cements of hydraulic kind. The main thing is that if there is sufficient silicic acid, the mortar will harden under water.

All these cements, burned under a low temperature, are slow hardening and only attain a fraction of the strength obtained by perfect calcination, in the modern cement plants using the higher temperature.

No wonder, then, that with the perfection of these plants, the new product has reached an extensive market all over the earth. The principal of these cements are portland cement and iron-portland cement, the latter being portland cement in which is mixed to the raw products some blast furnace slag, carefully ground.

The production of portland cement in Denmark has developed splendidly under the guidance of F. L. Smidth & Co., and as the Danish raw materials are particularly adapted for portland cement, our products compare well with the best in the world.

As is well known, the production of portland cement in Denmark consists of mixing about two parts of lime and one part marl in about 36% of water, and introducing the mixture at the cold and high end of an inclined kiln, 80 ft. to 250 ft. long from 6 to 10 ft. in diameter. At the opposite end pulverized coal is blown into the rotating kiln, so that the temperature reaches some 1500° C.

From the mixture water is first evaporated, then carbonic acid is eliminated, and finally the clay or marl is split by calcination into aluminum and anhydride of silicic acid, of which at this point each combines with the lime. The mixture then becomes lumpy, forming small nutlike clinkers, which drop out at the low end of the kiln, are cooled off and ground into what we name portland cement.

(C) The third group, according to gradation by temperature is Alcement, or, as it is named in French, Ciment Fondu (cast cement). This cement is produced either in the electric kiln, and therefore often goes under the name of Ciment Electrique, or in a cupola, water-jacketed as in the production of copper or lead, and is then named Ciment Fondu; both products are in Danish called Alcement.

The raw materials are lime and bauxite, the latter a granulated mass of earth with rich aluminum contents, the color being from white to gray or yellow to reddish. These materials are mixed and melted at temperatures considerably above the calcination temperature of portland cement.

After cooling, the glass-like black mass is pulverized and then looks like portland cement, but is the Alcement.

In a comparison between portland cement and the Alcement, we first call the attention to the fact that portland cement has shown great improvements by being burnt in rotary furnaces, making possible a higher and more uniform temperature, than in the earlier cupolas or kilns. The higher temperature increases the strength as it does the fineness, and it is usually demanded that the cement shall only leave 3% residue on a sieve of 900 meshes to the square centimeter. A finer cement is still stronger, which was proved by Borch & Gnudtzmann in 1891-94, when a cement that left 2.2% on a mesh of 4,900 to the sq. cm. gave 25% to 50% greater strength than normal cement, with 9.7% left on 4,900 meshes. Higher strength here really means the same as shorter time of hardening to the same strength, and one might think that portland cement might reach the same rapid hardening as Alcement by greater fineness, but this is not the case. Besides the fineness, the amount of calcium regulates the strength, so that the strength depends upon high temperature, fine grinding and rich content of lime.

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[1] Copenhagen, Denmark, April 26, 1922, as reported in *Ingenioren.*

The firm Poliet et Chausson, in Gargenville, has tried to produce Alcement in rotary kilns, but the results are not yet known.

Both portland cement and Alcement set in from one to two hours, but while portland cement keeps hardening for years, the *Alcement attains most of its strength in about 24 hours.* While the strength grows some the next few weeks, the increase is far less than for portland cement, and after a few weeks it is doubtful whether any appreciable increase takes place.

Alcement is ground to a fineness of 5% on a mesh of 4,900 to a sq. cm., and it is absolutely constant of volume, not containing any free lime.

The following comparison of cements shows that Alcement attains its strength after two days, and greater than other regular portland cements in 24 days, and from Mr. Paulsen's experiments we see that common portland cement increases in strength the first two years, while Alcement relatively increases less.

TABLE 1—COMMON PORTLAND CEMENT—AVERAGE FROM THE DANISH STATE TESTING LABORATORY

MIX 1:3

| | Compression | | Tension | |
|---|---|---|---|---|
| | lbs. per sq. in. Mean | lbs. per sq. in. Maximum | lbs. per sq. in. Mean | lbs. per sq. in. Maximum |
| Age: | | | | |
| 3 days | 1407 | 2800 | 193 | 333 |
| 7 days | 2750 | 3200 | 278 | 398 |
| 28 days | 4420 | 7800 | 365 | 604 |
| 3 months | 5400 | 8400 | 440 | 580 |

COMMON PORTLAND CEMENT—AFTER A. PAULSEN: "ZEMENT IM MEERWASSER"

MIX 1:3

| | Tension lbs. per sq. in. |
|---|---|
| Age: | |
| 7 days | 242 |
| 28 days | 346 |
| 90 days | 403 |
| 180 days | 418 |
| 1 year | 490 |
| 2 years | 520 |
| 4 years | 523 |
| 6 years | 512 |
| 10 years | 520 |

ALCEMENT, CIMENT FONDU—FROM "DE LAFARGE ET DU TELLS," FRANCE

MIX 1:3

| | Compression lbs. per sq. in. | Tension lbs. per sq. in. |
|---|---|---|
| Age: | | |
| 1 day | 5000 | 412 |
| 2 days | 5500 | 482 |
| 3 days | 5700 | 500 |
| 7 days | 6120 | 512 |
| 28 days | 6720 | 540 |
| 1 year | 9230 | 710 |

SPECIAL CEMENT—HOLDERBANK—FROM ARGOVIENNE, SWITZERLAND

MIX 1:3

| | Tension lbs. per sq. in. |
|---|---|
| Age: | |
| 1 day | 428 |
| 2 days | 420 |
| 7 days | 570 |
| 28 days | 703 |

ALCEMENT, "CIMENT ELECTRIQUE"—FROM M. BIED, IN FRANCE

MIX 1:3

| | Tension lbs. per sq. in. |
|---|---|
| Age: | |
| 1 days | 468 |
| 2 days | 480 |
| 7 days | 488 |
| 28 days | 665 |

The Swiss cement plant, Argovienne, produces a cement named Holderbank, which is claimed to harden about as fast as Alcement, which is the reason for including this cement in the later shown comparisons.

TABLE 2—AVERAGE ANALYSIS OF PORTLAND CEMENT FROM 91 SAMPLES IN 79 GERMAN CEMENT PLANTS IN THE YEAR 1903—PERCENTAGES IN WEIGHT

| | | Average | Minimum | Maximum |
|---|---|---|---|---|
| Lime | $CaO$ | 63.14 | 57.26 | 67.64 |
| Silicic acid | $SiO_2$ | 22.20 | 20.05 | 28.82 |
| Clay | $Al_2O_3$ | 7.39 | 4.43 | 9.64 |
| Iron oxide | $Fe_2O_3$ | 3.00 | 0.69 | 5.99 |

Besides a few per cents of magnesia, sulfuric acid and alkalies.

The principal part of portland cement is tricalcium silicate, $SiO_2, 3CaO$.

Candlot's sulpho-aluminate is $3(SO_3CaO)Al_2O_3,3CaO,3OH_2O$.

Hydraulic modulus is

$$\frac{CaO}{SiO_2 + Al_2O_3 + Fe_2O_3} \quad \begin{matrix}\text{less than 2.2} \\ \text{more than 1.7}\end{matrix}$$

$$\frac{\text{Silicic acid}}{\text{clay}} \text{ is more than 2.5.}$$

Alcement is approximately of this composition:

| | | Per Cent |
|---|---|---|
| Lime | $CaO$ | 40 |
| Silicic acid | $SiO_2$ | 10 |
| Clay | $Al_2O_3$ | 40 |
| Iron oxide | $Fe_2O_3$ | 10 |

Bauxite:

| | Villeveyrac (Herault) | Baux. | Baux. |
|---|---|---|---|
| $Al_2O_3$ | 78.1 | 57.6 | 58.1 |
| $Fe_2O_3$ | 1.0 | 25.3 | 14.2 |
| $SiO_2$ | 5.8 | 5.9 | 28.9 |
| $H_2O$ | 15.1 | 11.2 | 14.3 |

The principal part of Alcement is:

$Al_2O_3,CaO$ — $Al_2O_3,2CaO$ — $3Al_2O_3,5CaO$ (Day) — $5Al_2O_3,3CaO$ (Spackmann) — $0.40(SiO_2,2CaO) + (Al_2O_3,CaO)$ (Bied)

For the average German portland cement we note: The greater the hydraulic modulus, the stronger is the cement, and the German official ruling is that this modulus shall be greater than 1.7 and less than 2.2, with an average of 1.95. In the 91 samples above shown (Table 2) the average was 1.92. The relation of the silicic acid to clay is to be 2:5.

Alcement has the same contents, but in different proportions, and the hydraulic modulus becomes 0.66, and the relation of silicic acid to clay is only 0.25, or one-tenth of what hitherto has been considered a minimum. All our former theories as to proportions are thrown away; we are evidently dealing with an entirely different product, the qualities of which must be studied by tests and analyses.

Portland cement probably is no single chemical combination, but several, mechanically mixed, dissolved in each other, and by cooling brought out as microscopical grains, and the most important part is a tricalcium silicate, $SiO_3,3CaO$. However, this cannot be developed directly under the low temperatures of the kiln, so we must suppose that lighter fusible combinations have been formed, which have dissolved the lime and silicic acid separately, and acted upon these so as to make them crystallize as tricalcium silicate.

The setting of the cement is due to the fact that the water causes the hydrate of lime to precipitate in form of small crystals, which tie together the cement grains. If considerable clay is present in the raw materials, but little silicic acid, the cement usually sets quickly, but this is not the case with Alcement, which on the contrary, sets slowly, and certainly indicates that we are dealing *with a new material.*

Bauxite consists, as shown, of alumina, iron, silicic acid and water, somewhat differently proportioned at the different places. Its name is taken from the city of Baux (Bouches du Rhone), in France, but is also found at Le Var, l'Herault, l'Ariege, in Kaernthen and in the Caucasus, and is the usual raw material for the production of aluminum, first by producing oxide of aluminum, which by waterpower in Switzerland and Norway, principally, is reduced to aluminum.

While in portland cement the hydraulic qualities are due to the tricalcium silicate, the aluminates only acting during the period of setting, the hardening in Ciment Fondu is entirely due to the formation of aluminates, as the tricalcium silicate here is substituted by bicalcium silicate, which is inactive.

### Alcement Proof Against Sulfurous Solutions

The portland cement is more or less affected by water containing sulfurous solutions, partly for physical reasons, partly chemical. The physical attacks are due to crystallizing of salts in the pores of the concrete, and the chemical ones to the formation of *Candlot's Sulfoaluminate* (see Table 2).

Candlot himself made an acid proof cement with only 50% lime, adding some gypsum, but it was of but poor strength. It was discussed at the congress of the International Societies for Testing Materials in 1909.

Both laboratory and field tests have proved Alcement proof against sulfurous solutions. The tests have been made by submerging cubes of porous concrete of Alcement in solutions of sulfates of lime or magnesium 18 grammes to the liter, which in time attacked portland cement but had no effect on Alcement.

Similar experiments were made under the supervision of the engineer, M. Sejourne, during 1916-17, near the Braus tunnel on the Nice-Coni R. R., where a cement was to be selected that would withstand the sulfurous waters in the ground. The Alcement blocks were exposed to the strongly impregnated water for two years without effect.

Sea water also can have some effect on common cement by the influence of the chlor and sulfur combinations of magnesia on the free hydrate of calcium formed during the hardening, but in Alcement there is no free hydrate, because the hardening takes place by the formation of hydrates of monocalcium-aluminate.

Bied, the inventor of Alcement, has called attention to the fact that while the proportions of the different raw materials in portland cement vary very little, the proportions for Alcement have quite a wide range.

The three combinations of Day, shown in Table 2; Spackmann's formula; and, finally, the most favorable combination, by Bied, are shown to differ considerably.

Bied's formula is 0.40($SiO_2$,2CaO) plus ($Al_2O_3$,CaO), and gives the percentages by weight of the contents of Alcement given in Table 2.

The theories of Le Chatellier are by no means bankrupted, but we must assume that they refer to a material which, like portland cement, is produced by fusion in a rotary kiln, but do not answer for cement produced by melting.

Metallurgists know that quite different products may be obtained simply by different cooling, and the same is the case with Alcement.

Magny read a paper in l'Association Franco-Belge for Testing Materials, in which he recommended special formulas for calculations of reinforced concrete structures with Alcement, using *permissible stresses in concrete of 355 lbs. per sq. in. in tension and 2,120 lbs. per sq. in. in compression,* which certainly will show saving both in concrete and steel. However, I cannot see that tension stresses in concrete should be used or permitted, as the danger of cracks cannot be overlooked.

While the manufacture of Alcement is not so systematized as that of portland cement, a uniform article is being produced.

One ton of Alcement requires about 2,000 k.w. hours and 100 kg. electrodes, or 750 kg. cokes. There was a great difference to be found between the strength of the cement made in a small kiln of 20 k.w. and a large kiln of 1,500 k.w., the cement from the larger kiln being far superior. It takes some time to get the kiln to operate uniformly, but after 4 to 5 days the run becomes normal.

To verify the different statements as to the comparative strength of the Alcement, we had our branch in France, in charge of Holger Vilsboe and Capt. of Engineers Falking, with the world-renowned engineer, Professor Mesnager, director of the testing laboratories of France, as consulting engineer, make some practical tests with Ciment Electrique and Ciment Fondu, as well as the danger of cracks cannot be overlooked.

The before-mentioned great strength and rapid hardening is largely due to fine grinding, and in that connection we want to call attention to the fact that some difficulty is experienced in storing the cement, as it lumps easily, due to the fact that the cement grains have a large surface in proportion to their weight.

Our tests consisted partially of pouring and driving of reinforced concrete piles, partly in pouring and loading of test beams.

### The Driving Tests

On January 12, 1922, six piles were cast, numbered 1 to 6, inclusive. Nos. 1 and 2 were cast of Ciment Electrique; 3 and 4, Ciment Fondu; and 5 and 6 of cement Holderbank. The mix in all cases was the same, 1:1.5:2.5, mixed in the usual manner, and the piles were 6 in. by 6 in. by 16 ft., reinforced by 4 3/8-in. round rods tied 4 in. o. c.

On January 16, 1922, six more piles were cast of the same mix and numbered 7 to 12, inclusive. Nos. 7 and 8 were cast of Ciment Electrique; 9 and 10, of Ciment Fondu; 11 and 12, of cement Holderbank.

On January 19, 1922, 7, 8, and 9 were driven. (See Table 3.) The hammer was 750 kg.

These piles, only three days old, withstood the driving well, and at the last only penetrated 2½ cm. (1 in.) during a number of blows from the hammer, falling 3 m. (10 ft.).

On January 20, 1922, they drove No. 10, Ciment Fondu, cast January 16, 1922; No. 5, of Cement Holderbank, cast January 12, 1922 (see Table 4), and piles 1 and 2 of Ciment Electrique, also cast January 12, 1922.

An examination of the tests shows for No. 10, only 4 days old, as well as Nos. 1 and 2, both 8 days old, a most remarkable resisting power, while No. 5, of Cement Holderbank, 8 days old, was broken or crushed, which shows that this cement was not strong enough, even though cast 8 days.

On January 21, 1922, piles Nos. 3 and 4, of Ciment Fondu, 9 days old, as well as No. 6, of Holderbank, also 9 days old, were driven. (See Tables 5 and 6.)

These tests prove that Alcement piles may be driven when only 3 days old, and can stand blows from a 750 kg. (1,650 lbs.) hammer falling 10 ft., and a penetration of only 1 in. Trials and tests with piles 8 and 9 days old show that the piles do not become brittle, due to their rapid hardening.

While neat Alcement suffers a rise in temperature of up to 200 degrees in setting, this will cause no difficulties when the Alcement is used in concrete.

Some of the important uses of this quickly hardening cement are:

TABLE 3

| Pile No. 7 | | Pile No. 8 | | Pile No. 9 | | Pile No. 10 | |
|---|---|---|---|---|---|---|---|
| Ciment Elect.<br>Cast 1-16-22<br>Driv.1-19-22 | | Ciment Elect.<br>Cast 1-16-22<br>Driv. 1-19-22 | | Ciment Fondu<br>Cast 1-16-22<br>Driv. 1-19-22 | | Ciment Fondu<br>Cast 1-16-22<br>Driv. 1-20-22 | |
| Drop—met. | Penetration—cm. | Drop—met. | Penetration—cm. | Drop—met. | Penetration—cm. | Drop—met. | Penetration—cm. |
| 0.50 | 10 | 0.50 | 10 | 0.50 | 12 | 0.60 | 8.5 |
| 0.80 | 5.5 | 1.00 | 8 | 0.80 | 6.5 | 0.60 | 8 |
| 1.00 | 5 | 1.00 | 6 | 1.00 | 6 | 1.00 | 5.5 |
| 1.00 | 5 | 1.00 | 4 | 1.00 | 5 | 1.00 | 5.5 |
| 1.00 | 5 | 1.00 | 4 | 1.00 | 4.5 | 1.00 | 5.5 |
| 1.00 | 4 | 1.00 | 4 | 1.00 | 4.5 | 1.00 | 5.5 |
| 1.00 | 4 | 1.00 | 4 | 1.00 | 4 | 1.00 | 4 |
| 1.00 | 4 | 1.00 | 4 | 1.00 | 4 | 1.00 | 4 |
| 1.00 | 4 | 1.00 | 4 | 1.00 | 4 | 1.00 | 4 |
| 1.50 | 5 | 1.50 | 4 | 1.00 | 4 | 1.50 | 4 |
| 1.50 | 5 | 1.50 | 4 | 1.50 | 4.5 | 1.50 | 4 |
| 1.50 | 5 | 1.50 | 4 | 1.50 | 4.5 | 1.50 | 4 |
| 1.70 | 5.5 | 1.50 | 4 | 1.50 | 4.5 | 1.50 | 4.5 |
| 1.70 | 5.5 | 1.50 | 4 | 1.50 | 5 | 1.50 | 4.5 |
| 1.70 | 6 | 1.70 | 5 | 1.70 | 5 | 1.50 | 4.5 |
| 2.00 | 8 | 1.70 | 5.5 | 1.70 | 5 | 1.50 | 5.5 |
| 2.00 | 9 | 1.70 | 6 | 1.70 | 5 | 1.50 | 5.5 |
| 2.00 | 10 | 2.00 | 7 | 1.70 | 6.5 | 1.50 | 6 |
| 2.00 | 10 | 2.00 | 7 | 2.00 | 7.5 | 2.00 | 7.5 |
| 2.00 | 11 | 2.00 | 10 | 2.00 | 7.5 | 2.00 | 8 |
| 2.00 | 13.5 | 2.00 | 10 | 2.00 | 9 | 2.00 | 9 |
| 2.50 | 11.5 | 2.00 | 10 | 2.00 | 10 | 2.00 | 9 |
| 2.50 | 10 | 2.50 | 11 | 2.00 | 9 | 2.00 | 9 |
| 2.50 | 8 | 2.50 | 11 | 2.50 | 9 | 2.50 | 10 |
| 2.50 | 7.5 | 2.50 | 10 | 2.50 | 9 | 2.50 | 10 |
| 2.50 | 7.5 | 2.50 | 10 | 2.50 | 9 | 2.50 | 8.5 |
| 2.50 | 6.5 | 2.50 | 9 | 2.50 | 7 | 2.50 | 8.5 |
| 2.50 | 5.5 | 2.50 | 7 | 2.50 | 7 | 2.50 | 8 |
| 2.50 | 4.5 | 2.50 | 6 | 2.50 | 6.6 | 2.50 | 6.5 |
| 2.50 | 4.5 | 2.50 | 5.5 | 2.50 | 6 | 2.50 | 5 |
| 3.00 | 3.5 | 2.50 | 5 | 2.50 | 5.5 | 2.50 | 5 |
| 3.00 | 3 | 2.50 | 4.5 | 3.00 | 5.5 | 2.50 | 4 |
| 3.00 | 3 | 3.00 | 4.5 | 3.00 | 4.5 | 3.00 | 4 |
| 3.00 | 3 | 3.00 | 4 | 3.00 | 3.5 | 3.00 | 3 |
| 3.00 | 2.5 | 3.00 | 3.5 | 3.00 | 3 | 3.00 | 3 |
| 3.00 | 2.5 | 3.00 | 3 | A poor fit of the cushion caused the crushing of the upper 30 cm. of the pilehead | | 3.00 | 3 |
| 3.00 | 2.5 | 3.00 | 2.5 | | | 3.00 | 2.5 |
| 3.00 | 2.5 | 3.00 | 2.5 | | | 3.00 | 2.5 |
| | | 3.00 | 2.5 | | | 3.00 | 2.5 |
| | | 3.00 | 2.5 | | | 3.00 | 2.5 |
| | | 3.00 | 2.5 | | | 3.00 | 2.5 |
| | | 3.00 | 2.5 | | | 3.00 | 2.5 |
| | | 3.00 | 2.5 | | | | |
| | | 3.00 | 2.5 | | | | |

TABLE 4

| Pile No. 5 | |
|---|---|
| Cement Holderbank<br>Cast 1-12-22<br>Driv.1-20-22 | |
| Drop—met. | Penetration—cm. |
| 0.60 | 14 |
| 0.70 | 6 |
| 0.70 | 5.5 |
| 0.70 | 5.5 |
| 0.70 | 5.5 |
| 1.00 | 5 |
| 1.00 | |
| The pile crushed | |

TABLE 5

| Pile No. 1 | | Pile No. 2 | | Pile No. 3 | | Pile No. 4 | |
|---|---|---|---|---|---|---|---|
| Ciment Elect.<br>Cast 1-12-22<br>Driv.1-20-22 | | Ciment Elect.<br>Cast 1-12-22<br>Driv. 1-20-22 | | Ciment Fondu<br>Cast 1-12-22<br>Driv. 1-21-22 | | Ciment Fondu<br>Cast 1-12-22<br>Driv. 1-21-22 | |
| Drop—met. | Penetration—cm. | Drop—met. | Penetration—cm. | Drop—met. | Penetration—cm. | Drop—met. | Penetration—cm. |
| 0.50 | 15 | 0.50 | 14 | 1.00 | 18 | 1.00 | 18 |
| 0.75 | 10 | 1.00 | 5 | 1.00 | 10 | 1.00 | 7 |
| 1.00 | 9 | 1.00 | 5 | 1.00 | 7.5 | 1.00 | 5 |
| 1.00 | 5 | 1.00 | 4 | 1.00 | 5.5 | 1.00 | 5 |
| 1.00 | 4.5 | 1.00 | 4 | 1.00 | 5 | 1.00 | 5 |
| 1.00 | 4.5 | 1.00 | 4 | 1.00 | 5 | 1.00 | 6 |
| 1.00 | 5 | 1.00 | 4 | 1.00 | 5 | 1.00 | 6 |
| 1.00 | 5 | 1.00 | 4 | 1.00 | 5 | 1.00 | 7 |
| 1.00 | 6 | 1.00 | 4 | 1.00 | 5.5 | 1.00 | 7 |
| 1.00 | 6 | 1.00 | 4 | 1.00 | 6 | 1.00 | 7 |
| 1.00 | 7 | 1.00 | 4 | 1.00 | 6 | 1.00 | 8 |
| 1.50 | 7.5 | 1.00 | 4 | 1.00 | 6 | 1.50 | 9 |
| 1.50 | 7.5 | 1.50 | 4.5 | 1.00 | 7 | 1.50 | 10.5 |
| 1.50 | 8 | 1.50 | 4.5 | 1.50 | 8 | 1.50 | 12 |
| 1.50 | 8 | 1.50 | 6 | 1.50 | 8 | 2.00 | 12 |
| 1.50 | 8 | 1.50 | 6.5 | 1.50 | 8.5 | 2.00 | 10 |
| 2.00 | 10.5 | 1.50 | 7 | 1.50 | 10 | 2.00 | 9 |
| 2.00 | 10.5 | 1.50 | 8 | 2.00 | 10 | 2.00 | 7.5 |
| 2.00 | 9.5 | 1.50 | 8 | 2.50 | 13 | 2.00 | 6 |
| 2.00 | 9.5 | 1.50 | 10 | 2.50 | 10 | 2.50 | 5 |
| 2.00 | 8 | 2.00 | 10 | 2.50 | 10 | 2.50 | 4.5 |
| 2.50 | 7.5 | 2.00 | 10 | 2.50 | 10 | 2.50 | 4 |
| 2.50 | 6.5 | 2.00 | 9 | 2.50 | 6.5 | 2.50 | 4 |
| 2.50 | 4.5 | 2.00 | 8 | 2.50 | 5.5 | 2.50 | 3.5 |
| 2.50 | 4.5 | 2.00 | 8 | 2.50 | 4.5 | 2.50 | 3 |
| 2.50 | 4.5 | 2.00 | 7.5 | 2.50 | 4 | 2.50 | 3.5 |
| 2.50 | 4 | 2.50 | 6.5 | 2.50 | 3.5 | 2.50 | 3 |
| 2.50 | 3.5 | 2.50 | 5 | 2.50 | 3 | 2.50 | 3.5 |
| 2.50 | 3 | 2.50 | 4.5 | 2.50 | 3 | 2.50 | 3.5 |
| 3.00 | 3.5 | 2.50 | 3.7 | 2.50 | 3 | 2.50 | 3 |
| 3.00 | 3 | 3.00 | 3.5 | 2.50 | 3 | 2.50 | 3 |
| 3.00 | 2.5 | 3.00 | 3 | 3.00 | 3 | 3.00 | 3 |
| 3.00 | 2.5 | 3.00 | 3 | 3.00 | 3.5 | 3.00 | 3 |
| 3.00 | 2.5 | 3.00 | 3 | 3.00 | 3 | 3.00 | 3 |
| 3.00 | 2.5 | 3.00 | 2 | 3.00 | 3.5 | 3.00 | 3 |
| 3.00 | 2.5 | 3.00 | 2 | 3.00 | 3 | 3.00 | 3 |
| | | | | 3.00 | 3.5 | 3.00 | 2.5 |
| | | | | 3.00 | 3 | 3.00 | 2.5 |
| | | | | 3.00 | 2.5 | 3.00 | 2.5 |
| | | | | 3.00 | 2.5 | 3.00 | 2.5 |
| | | | | 3.00 | 2.5 | 3.00 | 2.5 |
| | | | | 3.00 | 2.5 | 3.00 | 2.5 |
| | | | | 3.00 | 2.5 | | |
| | | | | 3.00 | 2.5 | | |

TABLE 6

| Pile No. 6 | |
|---|---|
| Cement Holderbank<br>Cast 1-12-22<br>Driv.1-21-22 | |
| Drop—met. | Penetration—cm. |
| 0.60 | 16 |
| 0.60 | 7 |
| 0.60 | 5 |
| 0.60 | 5 |
| 1.00 | 5 |
| 1.00 | 5 |
| 1.00 | 5 |
| 1.00 | 8 |
| Broke by crushing. | |

Facilitating economical construction by shortening the time for removing the forms.

Reducing the time of hardening shortens the total time for construction.

Constructions may be executed with less interior supports, similarly to the usual steel constructions.

Concrete products need far less time for curing, hence less storage space.

Concrete ships require less time before launching and are absolutely safe against any action by sea water.

Larger span widths are made possible, owing to uniform interior stresses.

Considerable reduction of dead weights.

The Alcement or Ciment Fondu will not take the place of portland cement, as its cost is about three times that of the ordinary portland product, but it will increase the possibilities in the use of reinforced concrete.[2]

We are continuing our tests and experiments by the aid of Prof. Mesnager, in our French branch, and by the aid of Prof. Suenson in Copenhagen. I wish to compliment the French genius and talent that again has aided in enriching the technical world.

# Squeezing Out the Waste

In the field of building construction more material than is necessary is often used for a wall, column, or floor slab, because information concerning the stresses which such structures or members can safely bear, their ability to resist fire, etc., is inaccurate or incomplete. In order to more definitely formulate safe and economical standards in this field, the Bureau of Standards is investigating the suitability of rerolled steel as a reinforcement for concrete, the strength of walls and floors, the resistance of buildings to fire, and the constitution of cement and concrete.

If, through the above investigations and many others similar to them which might be mentioned, the Bureau can assist in preventing even a small portion of the avoidable waste in industry, the saving to the citizens of this country thus brought about would more than pay the cost of many research institutions as large as the Bureau of Standards for a number of years.

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A joint convention of the Mid-West Concrete Products Association and the Iowa Concrete Products Association will be held at the Rome Hotel, February 8, 9, 10. Frank Whipperman, secretary-treasurer of the organization, at 3045 Fowler avenue, Omaha, writes that he anticipates it will be one of the best meetings the organizations have ever held.

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[2] Translator's note: Inasmuch as the latest quotation for Ciment Fondu from Société Lafarge is fr. 280.00 per ton, and that of portland cement is fr. 170.00, the statement should be changed from "three times the cost of portland cement" to "twice the cost or less."

# Twenty Years' Progress in Cement Manufacture and Use

EDITORIAL NOTE

Many things make it especially appropriate and desirable that the progress in cement production and use be reviewed at this time. Market conditions of the last few years focussed public attention on cement manufacture as an industry. Some irate users of cement have gone so far as to refer very improperly to the Portland Cement Association as "a trust." Whatever, if anything at all, may have been accomplished in various sections of the country by groups of cement manufacturers to control and inflate the price of cement, certainly the Government has made out a very poor case. The Eastern manufacturers' trial resulted in jury disagreement, and other prosecutions show little progress toward trial. At all events, the Portland Cement Association is not and has not been on trial. It is not "a trust." It is a frankly promotional organization, whose work is based upon very broad educational policies—its technical men stand high in technical society work.

The Portland Cement Association appears to have accepted the very sound principle that a commodity can be promoted successfully on a long time basis only by telling the truth about its advantages and its limitations. It is this organization which has just celebrated its twentieth anniversary. It is proper to point out what progress has been made. It is also appropriate to consider this progress now when there is widespread interest in new European cements, which have special characteristics, making them desirable for many kinds of work in which quick hardening becomes a very important consideration.

## The Work of the Portland Cement Association

In a progress review of 20 years, issued by the Portland Cement Association in commemoration of its twentieth anniversary meeting, points of interest in the history of the association and of the progress in the manufacture and use of cement are reviewed by members who have been actively connected with the Association's work. In a character sketch of the association by Lester C. Sunderland, the retiring president, it is cited that "all honor is due to those courageous and unselfish pioneers who founded and nursed through infancy to lusty youth and seasoned maturity, this institution created from a dream of a loyal devotion to a cause for the common good."

The sketch briefly defines the Association's activities:

(1) Its aim is to increase the knowledge, utility, and use of portland cement through scientific investigation, public education, and associational promotion.

(2) It sells the "use of cement" but not the commodity, hence it is not concerned with prices nor other trading relationships between its members and their patrons. It cares not what brand of cement is used provided it comes from member's mills, the quality of whose product is known beyond reproach.

(3) It performs only such functions as cannot as well, if at all, be performed by its members individually.

(4) It undertakes only such activities as are for the common good and whose benefits when utilized flow alike to all contributing members.

(5) Its conduct is jealously guarded and made to conform scrupulously in all respects to the highest concept of commercial morality and the strictist interpretation of the laws of the land.

Congruent with these precepts it manifestly cannot engage in any attempt to solve individual manufacturing problems of its members except where their nature is such as to invest them with common interest and their solution would either directly benefit all alike or otherwise protect the whole industry against unfavorable reaction that would likely result from their neglect.

## "Progress" is Discussed by William M. Kinney, General Manager, Portland Cement Association

William M. Kinney, general manager of the association, outlines the commercial idea which predominated the first gathering of American portland cement manufacturers. This is cited as explaining the existance of the Portland Cement Association which is now supported by practically all of the cement manufacturers in the United States and Canada, and some in Cuba, Mexico, Uruguay and Argentine.

There are 24 district offices, one in Canada and the other 23 located throughout the United States so as to be most convenient for rendering the greatest service to the public at large. That the manufacturers of cement recognize their responsibility to the public is evidenced by the constant effort they put forth through the coordinated work of the association to prevent abuse or misuse of their material as well as to advance its proper use.

A few of the high lights in the onward march of the *Age of Concrete* are described.

## "Twenty Years Ago—And Today" Contrasted by Robert W. Lesley, First President of the Association

In referring to the conditions governing the organization of the association, in its formative period and at the present time, Robert W. Lesley, honorary member and first president of the Portland Cement Association, pointed out the remarkable fact that a gathering of men, all intent upon the money-making side of their business and establishing an American industry against a firmly entrenched foreign competition, met in the furtherance of their business interests upon a call to deal with "the present methods of handling the subject of sacks, which are almost universally unsatisfactory." Out of the meeting called to deal with this strictly commercial proposition grew the scientific and promotional organization now known as the Portland Cement Association.

Looking back to this early period, it will be found that almost every field of development to which in its perfected form the association is now devoted, had its inception in the minds of that little band of twenty odd men who formed the Eastern Portland Cement Association in 1902.

The two purposes in the minds of these early workers mark the organization today: the desire for a standardization of specifications for cement, for concrete and for all that would lead to the supplanting by systematic procedure of a then chaotic condition among manufacturers; second, the sincere and prolonged service to the users of cement, is one in which the industry can challenge any other in the world, a service whose growth has been concurrent with that of the association itself.

In brief, then, the association in the early days represented what it now stands for, namely, concerted effort in behalf of the industry as distinguished from individual endeavor. After its foundation it soon became the forum or clearing house for the sifting of facts calculated to be of value to the individual manufacturer in the operation of his plant. It revealed the importance of the industry as a great national asset, thereby stimulating confidence in its future. As a body, it was more concerned in the proper and economic uses of cement than the prices thereof, thus putting the industry as a whole on a very high plane in so far as its relations to the engineering profession and the public were concerned.

The association became the official representative of the industry before technical, scientific, and legislative bodies. It has appeared on the platform and written text books. And in all of this work it has been as though its engineers, experts and other agents were working for a single manufacturer, for each has received its full benefits.

In looking back as a participant in all the activities of the association from the day of its founding until today, and having an equally intimate and practical knowledge of the industry during the years preceding the forming of the association, I feel that its organization was, in a sense, the establishment of stable government in the industry, entailing no sacrifice of individual initiative or enterprise such as obtained in the earlier period, when each was a law unto himself, but producing, instead of haphazard work and divided effort, a concentrated, definite, altruistic service for consumer, contractor, and engineer.

## F. W. Kelley, New President, Outlines Development of Specifications and Research

The United States at first imported its portland cement specifications with its portland cement. As the industry became better established in this country, many different ideas developed as to the methods which should be used in testing, and as to the requirements to be included in the specifications.

In 1884 a committee of the American Society of Civil Engineers made a preliminary report on a uniform method of tests for cement. It was adopted as a final report in 1885, and until 1903 was considered in this country the most reliable guide to a proper method of procedure.

In the '90s cement improved in quality as fast as in quantity, and the former methods of tests in some cases became unsuitable.

Up to this time a different specification was used on almost every job. In 1898 R. W. Lesley, who later became the first president of the association, presented at the Engineers' Club in Philadelphia a compilation of the more important requirements of ninety-one specifications, scarcely two of which were alike. In many cases, the specification requirements were contradictory, and if strictly followed would in some cases impair the quality of the cement.

Shortly after the 1903 report of the A. S. C. E. committee on methods of testing was presented, a proposed set of uniform specifications was prepared by a committee of the then recently organized American Society for Testing Materials, in cooperation with committees of the American Railway Engineering Association, the American Institute of Architects, and of our own association, at that time called the Association of American Portland Cement Manufacturers, then but recently formed. These specifications were adopted by the A. S. T. M. on November 11, 1904, and soon afterwards by the other organizations. This can properly be called the first uniform specification in this country which was at all generally recognized.

The final steps leading to the real uniform specification were taken when, in 1912, a Joint Conference on Uniform Methods of Tests and Standard Specifications for Cement was formed, representing the A. S. C. E. and A. S. T. M. and the United States Government. These organizations had recommended specifications and methods of tests in 1909 and 1912.

In the specifications in the '80s and early '90s the fineness of cement was measured on the 50 and 100-mesh sieve, there being no mention of the 200-mesh. At the present time there is no mention of the 50 and 100-mesh sieves, and 78% of standard portland cement must pass the 200-mesh sieve. In the the early '80s and '90s the tensile strength was largely measured by neat cement, and the mortar strength requirements were substantially one-half the figures now insisted upon. Today the neat test, which has little real value in measuring the quality, has been entirely abandoned, and the mortar test is not only required to give figures over twice the earlier strength requirements, but the amount of mixing water used in the mortar test has been increased to such an extent that an additional 10% in strength is required in the cement, as compared with the old methods of testing.

Cement specifications are an attempt to define certain characteristics which a cement should show when tested in a laboratory. Confidence in being able to weigh properly proposed changes is largely based upon our ability now to make laboratory tests which give definite results, and there is great general recognition in engineering circles of the value of such researches.

### Laboratory and Research

Th first outstanding work of our association was the collective exhibit at the St. Louis Exposition in 1904. This included a testing room in which a large number of tests on reinforced concrete were conducted under the supervision of Richard L. Humphrey.

The first committee on Technical Research was appointed by President Lesley on January 10, 1905, with Dr. S. B. Newberry as chairman and thirteen other members.

The desire for an association laboratory finally took definite form early in 1906, with the appointment of a Committee on Association Laboratory, of which Edgar M. Hagar was chairman.

At the annual meeting in December, 1914, the report for an association laboratory was submitted, in which the plan and scope of the work was carefully considered, and considerable data relating to the work of the German Association Laboratory was presented.

The first definite steps which resulted in the establishment of our present laboratory were taken soon afterwards, when an appropriation of $500 was made for the investigation of impurities in sands, which work was being done at Lewis Institute under D. A. Abrams.

Professor Abrams at this time was working at Lewis Institute on special problems for the Universal Portland Cement Co. It was finally decided that Professor Abrams was the man we wanted for laboratory director, and the Universal Portland Cement Co. very generously withdrew any claims it had upon his services and left the field clear for his engagement by us, and for the conclusion on the 31st day of August, 1916, with Lewis Institute of the agreement under which we have operated ever since.

The first purpose as set forth in the agreement with Lewis Institute was:

"To carry out researches in the properties of concrete and concrete materials for the information of all users of concrete." This purpose has been steadily pursued, and when information was brought to the point where it was felt to be sound and to represent the truth, has been given to all interested. It is not a laboratory for promotion purposes, except where the truth aids promotion.

The principal claim which the laboratory can properly make for deserving confidence in the results is that it has succeeded in making tests of concrete in such a way that all the factors have been controlled, except the one studied in each case. By studying each factor through a wide range of variation, and by making a very large number of tests, it has brought out clearly the effect of each of the important factors in concrete making and so brought the knowledge on the subject into a consistent whole.

## Twenty Years' Progress in Mechanical Features of Cement Manufacture

By Joseph Brobston

Vice-President Dexter Portland Cement Co.

Twenty years ago the 10,000 tons of rock used per day by the entire cement industry in the United States was quarried by retail. Small holes were drilled a few feet back from the face of a 16 ft. cut and 500, 1,000 or 2,000 tons of rock were blown out, picked up by hand, after being sledged into small pieces (no piece over 100 pounds could be handled by the crushers then in use), hauled in carts to the crushers, dumped on the floor and fed into the small openings by hand.

Today more than one member of this association quarries this much stone per day for its individual use but does it by wholesale. Churn drills make large holes 20 ft. back from a quarry face of 60, 80, or 100 ft. depth and 25,000, 50,000 or 75,000 tons of rock are blown down with as little fuss as was 1,000 tons twenty years ago. The largest steam shovels have replaced the hand labor, enormous steel cars and either locomotives or hoists take the place of the horses and carts, and the stone is delivered in pieces weighing often a ton or more to crushers with openings into which the crusher of twenty years ago could be readily dumped.

The large stone storages of today were unknown. The crushers then delivered the stone direct to the dryers, which in turn delivered the stone, sometimes dry, sometimes not, to the bins over the mills. The modern dryer with partitions, plates, and other features, and frequently fired by pulverized coal, not only handles four, five or six times the amount of stone, but really dries it.

The coarse grinders of twenty years ago were good sized units if they turned out four or five tons of granulated rock per hour, whereas today an output of 40, 50, or 60 tons is not uncommon for one machine. The size of the pulverizing units has also increased so that a unit of two machines today does the work for which twenty years ago we would have required ten to twenty mills.

Twenty years ago the standard kiln was 60 ft. long and 6 ft. in diameter. Today kilns from 150 to 240 ft. in length and 8 to 12 ft. in diameter turn out five to ten times the amount of clinker it was then thought possible for a kiln to produce.

Twenty years ago cement men talked of waste-heat boilers, kiln insulation and preheating air as things desirable, but unattainable. Today no new mill would be erected without providing for all of them; and the rapid extension of knowledge as to these advances is largely due to the information secured through association study and research furnished to its members.

Twenty years ago much cement was still shipped in wood. Bags were either filled by hand or on bran packers; but when packers were used the weighing and tying were done by hand and the bags were trucked to the cars. Without the automatic tying and weighing machines now in use and the belts delivering the bags to the cars, it is doubtful whether today a packing house could be kept in operation.

A marked change has also taken place in the character of the buildings in the industry. When we look at the fireproof construction of today it is hard to realize that twenty years ago most of the insurance companies hesitated to issue policies on cement mills. Frame buildings predominated, and even when the buildings were of other construction, they had wooden roofs, platforms, elevator casings and runways.

The idea of guarding and protecting the machinery to prevent accidents was only in its infancy. A rough plank nailed in front of a gear was considered ample; and the wonderful advance in this respect is one of the finest achievements of the association typified by its educational work in accident prevention.

These changes in the mechanical efficiency of the plants of the members mean this in the way of progress:

Due to the installation of labor-saving devices and the increase in the size of the machines used, each man employed turns out 2½ barrels of cement where twenty years ago he turned out one; or, to put it differently, if we made cement as we did twenty years ago, we would have to employ two and one-half times as many men as we do.

Also, due to the saving of heat effected by the improvements to the kilns and the waste-heat boilers, and the saving of power from increased efficiency of grinding units (over the extra power required by labor-saving machinery installed), we make two-thirds of a ton of coal today do the work a ton of coal did twenty years ago, or, put the other way, if we had made cement this year as we did twenty years ago, we would have used 3,000,000 more tons of coal to make the same amount of cement.

## Progress in the Scientific Study of Portland Cement

By S. B. Newberry,[1]
Late President Sandusky Cement Co.

The past twenty years have witnessed the practically complete solution of the long-debated questions of the chemical constitution of portland cement clinker, the reactions which take place in the calcination of cement material, and the nature of the compounds formed in the process of setting and hardening. For more than a hundred years these reactions remained obscure. The Romans made mortar by mixing slaked lime with the sand most readily available which was a volcanic scoria called "Pozzulana," and found that such mixtures gained great hardness and were capable of hardening under water. We now know that this was due to reaction between the lime and the soluble silica contained in the volcanic sand, and that many other materials such as slag and burned clay have similar action. This volcanic scoria was used as an ingredient of mortar and concrete for eighteen hundred years, with little knowledge of the causes of its action. Smeaton, engineer of the Eddystone lighthouse, in 1756 made a study of different kinds of lime with regard to their suitability when mixed with puzzolana for mortar which would harden under water. He found that limes containing a considerable proportion of clay were the most effective, and stated, "I do not doubt to be able to make a mortar equal to portland stone." From this remark the name or portland cement is derived.

Smeaton's observations received little attention, and for seventy-five years thereafter various notions were held in regard to the cause of hardening. Bergmann, a Swedish chemist, attributed the hardening to the presence of traces of manganese, and this view appears for a long time to have been generally accepted. Vicat in 1818 made a thorough study of hydraulic materials and fully confirmed Smeaton's observations that this is due to the presence of clay in the limestone from which the lime is made. He showed that by burning artificial mixtures of lime and clay, products having hydraulic properties could be made, and that these properties are due to combination of the silica of the clay with lime. Later investigators arrived at more precise knowledge of the nature of this combination, but it was not until the problem was attacked by Le Chatelier in 1887 that a complete explanation of the nature of cement clinker and the hardening of cement was given. The writer called on Le Chatelier in 1913, who stated that his grandfather was a great friend of Vicat, and that when Le Chatelier selected a subject for his thesis for the degree of Doctor of Science, the samples of cement made by Vicat, which had been carefully preserved by his grandfather, aroused his interest and led him to choose the subject of hydraulic cements for his investigation.

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[1] Dr. S. B. Newberry died suddenly while driving to his office in Cleveland, Ohio, Nov. 28, 1922.

Le Chatelier showed that the chief constituents of cement clinker are tri-calcium silicate and tri-calcium aluminate; that is to say, three molecules of lime combine with one molecule of silica and alumina, respectively. When cement is ground and mixed with water, these substances form hydrated crystalline compounds, hydrated calcium silicate, hydrated calcium aluminate, and calcium hydrate, and it is because of this crystallization that cement hardens. It is interesting to note that the conclusions reached by Le Chatelier thirty-five years ago, although often disputed, are now firmly established.

After the days of Le Chatelier the scene of successful scientific investigation of cement shifted to the United States, and the great work which has been done in this field in recent years has been that of Day and Shepherd, and Bates of the Bureau of Standards, and Rankin of the Geophysical Laboratory. By the use of modern methods and appliances which had not been developed in the days of Le Chatelier, these American investigators have been able to give exact proof of the nature and properties of the constituents of clinker, and of the crystalline substances formed in the hardening.

The chief point of dispute in regard to Le Chatelier's conclusions has been the existence of tri-calcium silicate. Le Chatelier, Day and Shepherd were unable to produce this compound by calcining mixtures of pure lime and silica, even at very high temperatures, and Day and Shepherd reached the conclusion many years ago that it did not exist. The later investigations of Shepherd, Rankin and Bates have shown that this tri-calcium silicate is formed in the presence of very small amounts of alumina, boracic acid or chromium oxide, and that it is actually present in considerable quantity and in definite crystals recognizable with the microscope in portland cement clinker. This clinker consists, as most clearly set forth by P. H. Bates of the Bureau of Standards (Journal of the Franklin Institute, March, 1922), of tri-calcium silicate, di-calcium silicate and tri-calcium aluminate. The other materials present, chiefly magnesia and iron oxide, are in the form of a non-crystalline flux or glass which is present in small quantity, containing more or less silica, alumina and lime. Bates has been able to prepare these principal constituents in a condition of practical purity, and to study their properties, including the strengths developed in their hardening. Tri-calcium silicate has all the properties of portland cement and shows high strength, especially at short periods. Di-calcium silicate, containing less lime than the tri-silicate, is very slow in hardening, but develops high strength at long periods. The tri-calcium aluminate sets almost instantaneously and contributes but little to the strength. The best cement appears to be that containing considerable proportions of both of the lime silicates thus developing early strength and continuous gain at long periods. By increasing the lime it is possible to make clinker consisting chiefly of tri-calcium silicate with little or no di-calcium silicate. Such clinker requires however a very high temperature in burning, and appears to possess no qualities which would justify the greater cost of making. These observations throw clear light on the practical problems of cement making and fully explain what proportions of constituents are most desirable from the point of view of quality of product and cost of manufacture. One of the most significant practical suggestions is given by Rankin (Journal of Franklin Institute, June, 1916), first stated by Richard K. Meade, that there are three factors in making clinker which tend to bring about equilibrium and the production of the largest amount of active hydraulic constituents. These are:

First; Fineness of grinding of raw materials;
Second; Temperature of burning;
Third: Length of time of burning;

Increase in any one of these will overcome deficiency in the others; for example, extremely finely ground raw material will combine at lower temperature and in shorter time than coarse raw material. Higher temperature or longer duration of burning may replace extreme fineness of raw grinding. This is very significant and has a practical bearing on the manufacturing process. From a practical point of view, there is still much to be done to answer the question, "How good can portland cement be?"; that is, what strength, resistance to abrasion and other desirable qualities can *possibly* be developed by exact proportions of material and best possible raw grinding and burning?

The writer hopes most earnestly than our association may take a more active part in the investigation of problems of this character. Our laboratory has already done an immense amount of valuable work on the best methods of using cement, the proportioning of concrete, the prevention of destruction by alkali waters, and along many other lines, and in these fields has done scientific work of the highest value. It has as yet, however, because of the many other problems it has had to study, been unable to take much part in the scientific study of cement manufacture or of the chemical composition of clinker and the reactions in the hardening of cement. As these problems intimately concern the industry, our association laboratory will no doubt extend its work in these fields.

The subeject of the hardening of cement through its crystallization by combining with water has been ably investigated by Klein and Phillips of the Bureau of Standards (Technologic Paper No. 43, 1914). They have shown that this crystallization consists of the formation of hydrated tri-calcium aluminate, calcium hydroxide in hexagonal crystals, and non-crystalline (amorphous) hydrated calcium silicate. It is interesting to note that these observations confirm almost completely the conclusions advanced by Le Chatelier in 1887, although through further study and the use of exact modern scientific methods they have greatly expanded and clarified our knowledge of the process of hardening.

## Pipe for Irrigation

Many uses of concrete in irrigation—concrete pipe and special fittings—are described and illustrated in a pamphlet recently issued by the Portland Cement Association: "Concrete Pipe for Irrigation"; 20 pages and cover, 6 in. x 9 in. The publication also contains numerous illustrations from line drawings supplied by Prof. S. H. Beckett, University of California, showing the modern methods of irrigating land by concrete pipe systems.

# Concrete Dams—A Controversy 20 Years Ago

Engineers, architects and builders had not acquired the "concrete idea" twenty years ago as they have today. Nowadays when one thinks of structures such as dams, retaining walls, bridge piers, abutments, foundations, and other structures of similar character, he thinks at once of concrete, which has now supplanted stone and brick masonry in structures of this kind.

Twenty years ago the situation was quite different. This is well illustrated by a letter published in the January 23, 1902, issue of *Engineering News* (two years before the first issue of CONCRETE), this letter having been published as the final word in a controversy over the suitability of the type of construction selected for a masonry dam in the South.

The letters were the direct result of a sudden interest in masonry dams, aroused by the fact that heavy rains and swollen streams had carried out four large dams of this type in the south, in December, 1901. Engineering magazines for some months following published numerous letters and articles pertaining to the subject of masonry dams. Many of the letters were of a controversial nature.

In the issue of January 16, 1902, a letter writer took exception to a form of construction used in a masonry dam 40 ft. high in the Tallapoosa river, near Montgomery, Ala. This dam was built with granite masonry quarried from the bed of the river. Both the upstream and down-stream sides were laid carefully with cement mortar beds and joints. Portland cement was used on the upstream side only. On the downstream side there was also a layer of concrete averaging 2 ft. in thickness. The central portion of the dam, which was very large in volume, was built by placing large rough stones and filling all spaces between them with smaller stones, then packing the spaces between smaller stones with spawls so as to form as nearly as possible a solid mass of rock without mortar. After building up rubble courses of this kind about 4 ft. at a time, grouting boxes were set in place and the spaces between the spawlls were filled with liquid cement, or cement grout, as it is more commonly called.

The writer, who took exception to this method of construction, took the position that the joints would in reality not be filled, and that in consequence the dam was sure to fail because of the water that would penetrate it. His contention was that the entire dam should have been laid up in courses, with the joints well bedded.

In the issue of January 23, the builder of the dam came back with his answer. He stated that he had always found in actual field work that masons think it very clever to slip something over on the inspector by not flushing the mortar joints, and then covering up their poor workmanship. Masons, he said, had as a rule, very little experience in laying up masonry such as dams, and were accustomed to use only sufficient mortar to give the appearance of good workmanship, without in reality filling the joints. Consequently they inwardly resent being told to do their work differently. This attitude, he said, was almost universal among them. As a result, although this engineer formerly adhered to standard specifications and tried to build masonry dams as ordinary masonry, he found that he obtained better results by using the grouting method.

Then at the end of this letter appears a significant foot-note by the editor of *Engineering News.* "Would not a well-made concrete," says the editor, "with large stones imbedded in the mass, be as cheap as either the rubble masonry or the grouted construction, and better than either in strength and solidity?"

The significance of this story is the fact that the two engineers who engaged in this controversy, although both of them were hydraulic engineers, had never thought of concrete as a suitable material for the construction of heavy dams. In other words, they had not acquired the "concrete idea." The editor, on the other hand, had doubtless traveled around over the country much more than either of the two engineers, had seen more varied forms of construction, and had become familiar with some of the possibilities of concrete.

Today no one thinks of building masonry dams of any material other than concrete, all of which proves that the editor was right.

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# Concrete Transmission Poles Cast in Place

The Helderberg Cement Co. has recently built a power transmission line, carried on tall concrete poles, cast in place. While precast poles are being quite commonly used in several sections of the country, poles of this size seldom if ever have been constructed in place. The work was undertaken under the direction of Frederick W. Kelley, President of the Helderberg Cement Co., the new president of the Portland Cement Association, and for some time chairman of its Technical Problems Committee.

The poles shown in the accompanying illustration are 27 ft. to 34 ft. from ground line to the lower cross arm, depending on the location. They are eight inches square at the top, tapering at the rate of ½ in. to the foot toward the base. Cross arms were cast integral with the pole proper, a very desirable feature, which up to the present time has been used but infrequently.

After the footings were in place, forms for the poles were erected complete except for one side. The reinforcing was then placed and sections of the fourth side of the form put on one after another when the concrete as deposited reached the top of each. In this way it was possible to spade carefully all form surfaces and avoid blemishes. The completed poles are structurally sound in every way and of unusually good appearance.

Erection was found to be simple and eliminated the difficulty of setting heavy poles of this kind molded on the ground. Mr. Kelley feels that the solidity of poles made monolithic with the foundations is superior to that of poles set up in a hole with concrete poured around them. The cost was estimated at a little over $60 per pole, very little more than for plain wooden poles of comparable size.

These concrete poles are located at the Howes Cave works of The Helderberg Cement Co., and are used to carry an electric transmission line consisting of six 500,000 circular mill cables, furnishing power to the cement plant, which has a daily capacity of some 2,000 barrels.

# Building Road a Mile a Week

The Aaby-Maturi Co., Chisholm, Minn., paved a section of the Miller trunk highway between the Mesaba Range and Duluth at a speed of a mile a week. The construction just completed included 15.1 miles of road beginning at Martins' Siding and extending towards the Mesaba Range. Although these contractors were also awarded the contract for the construction at the same time of a section from Eveleth to Central Lakes, the sections were some distance apart, with the result that it was necessary to lay out two complete plants, differing only in details.

Construction began on May 8 and was completed September 2. In this period many performance records were made. The mixer was of the usual 21 cu. ft. size. Throughout the construction period a weekly average of 5,125 ft. per week was attained. The daily average over this extended period (a season's work) was 855 ft. The highest daily run was the paving of 1,260.6 ft. On 12 different days 1,000 ft. or more were constructed.

Frank Aaby and Raymond Maturi, partners in the construction company, personally supervised the work. R. W. Acton, chief engineer of St. Louis county, was the engineer in charge and under him were Peter Huntington, chief inspector of Miller trunk highway, and four men in direct contact with the engineering and inspection work.

At the gravel pit, where raw material was washed and screened, a central proportioning plant was built. Cement was received on sidings at Alborn and Martins, and during the laying of the road from the far end to the center it was transported by the industrial railway to the central proportioning plant. After the construction work reached the proportioning plant, the cement was stored in a house on the subgrade, which was moved twice a week. The paver was charged from batch boxes brought up on cars by locomotives on the industrial haulage system. With the establishment of the central proportioning plant at one point, the expense of moving the plant was eliminated and it was only necessary to move the industrial haulage system.

The slab was constructed according to the 1922 Minnesota specifications. The pavement is 18 ft. wide, 7½ in. thick, with steel rod reinforcement; the mix, 1:2:4.

### Batch Box Loading Plant

The loading or proportioning plant, as before mentioned, was placed at the gravel pit in the center of the contract. The gravel was excavated by shovel and loaded into small bottom-dump cars which were dumped and raised by bucket elevator to the top of the plant. Oversize stone was returned to the pit. Sand and coarse aggregate was moved by cars on trestles and belt conveyors, and dumped onto stock piles over separate charging tunnels. The sand tanks, revolving screens, elevators and washing equipment were of the Telsmith type. Ample capacity was provided in the plant and at times as much as 12,000 yds. of coarse aggregate was available in the stock piles.

The batch box cars were spotted under the hoppers in the sand and gravel loading tunnels, and the boxes filled from improvised batchers. Cement was also added at this point or later in the job from a shed placed on the subgrade. With aggregate supplies at hand locally, no dependence was placed on railroad transportation, except for cement, and the railroad strike failed to affect the progress on the work.

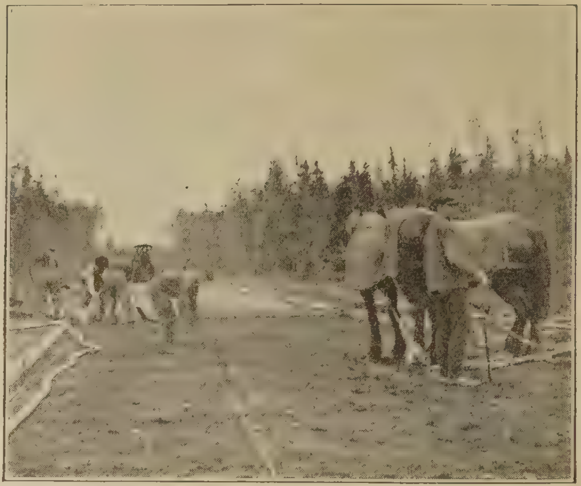
Fig. 1—Team Scrapers on Coarse and Roller with Subgrader Completing Fine Grading on Subgrade, on Aaby-Maturi Contract

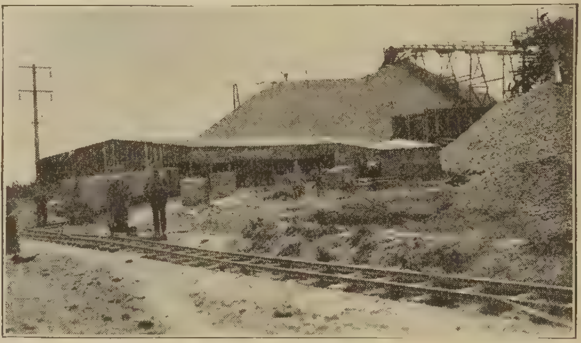
Fig. 2—Central Proportioning Plant at Gravel Pit, Showing Charging Tunnel and Cement Shed

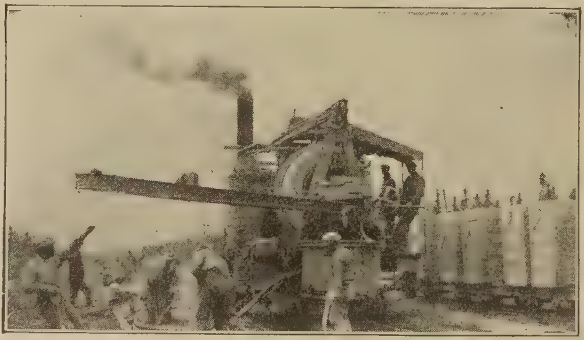
Fig. 3—Laying a Mile of Concrete Road Every Week on Aaby-Maturi Contract Between Mesaba Range and Duluth

The paver was mixing almost continuously. In order to accomplish this it was necessary that sufficient material be available not only in the stock piles but in batch boxes at the paver. American batch boxes holding 37 cu. ft. of material were used, and two were mounted on each industrial car. Koppel cars were used, with eight cars to a train. Another factor almost as important as having the materials available was the coordination between the batch box derrick and the loading skip of the paver used on the work.

### MATERIAL HAULAGE

Cars with two 37 cu. ft. boxes to each car were drawn to the mixer, 8 in a train, by five Plymouth seven-ton locomotives. A pusher locomotive was also used on heavy grades. Light weight industrial rail laid on wood ties was used, the road shoulder serving as roadbed.

### CONCRETE MIXING

The concrete was mixed and placed on the sub-grade by a 21-E Smith paver, using a five-bag batch of 1:2:4 proportions. The mixer traveled under its own power on full length traction. Concrete was placed on the sub-grade by means of a boom and big cross-dump bucket distributing device.

Water for mixing the concrete and also for sprinkling the completed pavement during the curing process was pumped an average distance of 2½ miles from the St. Louis and Cloquet rivers.

### FINISHING

The fresh concrete, after being laid in a ribbon on the sub-grade by the bucket traveling along the boom of the mixer, was further spread by men with shovels and rakes. The machine finisher then struck off to proper level and tamped the wet concrete, and by means of an oscillating belt gave the concrete the final surface finish.

Curing was accomplished by covering the newly laid concrete with earth. The earth was then sprinkled daily and served to hold the moisture to the surface of the concrete.

### WORKERS' QUARTERS

Nearly 120 men were required to handle the proportioning plant, haulage system, grading, paving, finishing and curing. Some of the crew came from nearby towns, while others, coming from greater distances, had to be accommodated in a company camp. The camp buildings were erected at the gravel pit and proportioning plant. A portable camp for the paver crew was mounted on skids on the sub-grade, and moved several times each week. The men were charged only enough board to pay actual expenses. CONCRETE is indebted to the T. L. Smith Co., Milwaukee, for this information.

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## Chicago Own-Your-Home Show

Chicago's Third Annual "Own-Your-Home" Exposition will be held at the Coliseum March 24 to 31. Nearly one hundred organizations and trade associations, representing all branches of the building and building materials industries, have been invited to participate.

The Chicago Real Estate Board has this exhibition immediately under its supervision, assisted by the real estate boards of Oak Park, Evanston, Harvey, North Shore and Du Page County.

Organizations in the concrete field such as the American Concrete Pipe Association, Hollow Building Tile Association, Concrete Mixer Association, and the Portland Cement Association have been asked to cooperate. The officers of these organizations have been asked to appoint a committee to represent the concrete industry to show the advantages of building with concrete and using concrete products in and around the home.

## Road Show and Convention

The Thirteenth Annual Good Roads Congress inclues the annual convention of the American Road Builders' Association, at the Congress Hotel, Chicago, January 16, 17, 18 and 19, and the Good Roads show at the Coliseum and adjoining buildings, January 15, 16, 17, 18, 19. It is promised that the show will surpass in number and variety of exhibits the show of 1922. The convention program is skeletonized as follows:

Tuesday, Jan. 16, 10 a. m.—"Continued Highway Expenditures Required to Meet Traffic Demands of the Future," Thomas H. MacDonald, Chief, United States Bureau of Public Roads, Washington, D. C.; "Progressive Construction of Highways," (a) Practice in North Carolina, C. M. Upham, State Highway Engineer, North Carolina; (b) Practice in Iowa, C. Coykendall, Assistant Chief Engineer, Iowa Highway Commission; "The Obligation of the State Highway Department to Keep the Public 'Sold' on Highways," H. E. Hilts, Acting Chief Engineer, Pennsylvania State Highway Department, Harrisburg, Pa.

### DESIGN

Tuesday, Jan. 16, 2:30 p. m.—"What Test Road Results Have Taught Us": (a) Bates Test Road, Clifford Older, State Highway Engineer of Illinois, Springfield, Ill.; (b) Pittsburgh Test Road, Lloyd Aldrich, Consulting Engineer, San Francisco, Cal.; (c) Arlington Tests, A. T. Goldbeck, Engineer of Tests, United States Bureau of Public Roads, Washington, D. C.; "Development of Apparatus for Field Testing of Roads," H. F. Clemmer, Testing Engineer, Division of Highways, Springfield, Ill.; "Developments in the Use of Local Materials," Vernon M. Pierce, District Engineer, United States Bureau of Public Roads, Washington, D. C.; "Designed Subgrade," C. M. Upham, State Highway Engineer, Raleigh, N. C.

### CONSTRUCTION

Wednesday, Jan. 17, 10 a. m.—"Haulage Methods in Highway Construction": Industrial Railways, A. J. Parrish, General Contractor, Paris, Ill.; Heavy Truck Haulage, Charles H. Fry, Charles H. Fry Construction Co., Erie, Pa.; Light Truck Haulage, A. E. Horst, Henry W. Horst Co., Rock Island, Ill.; "How to Equip and Operate Local Gravel Pit to Produce Concrete Aggregate," H. E. Kuelling, Construction Engineer, Wisconsin Highway Commission, Madison, Wis.; "How Much Time Is Lost in Delays in Highway Building?": H. K. Davis, Chief Inspector, Iowa Highway Commission, Ames, Ia.; Discussion, B. M. Piepmeier, State Highway Engineer of Missouri, Jefferson City, Mo.; "What Road Building Work Can Be Done in Winter?" John H. Mullen, Chief Engineer, Minnesota Highway Department, St. Paul, Minn.

### MAINTENANCE

Thursday, Jan. 18, 10 a. m.—"Organization of Intensive Maintenance on a State Highway System in Eighteen Months," Frank Page, Chairman, North Carolina State Highway Commission, Raleigh, N. C.; "Four Years' Experience with Patrol Maintenance in Wisconsin," J. T. Donaghey, Maintenance Engineer, Wisconsin Highway Commission, Madison, Wis.; "Gravel Road Maintenance Practice in Michigan," L. H. Neilsen, Deputy State Highway Commissioner of Michigan, Lansing, Mich.; "Blade Grader and Road Drag Earth-Road Maintenace in Iowa," W. H. Root, Maintenance Engineer, Iowa State Highway Commission, Ames, Ia.; "Salvage and Maintenance of Macadam Roads," W. A. Van Duzer, Assistant Maintenance Engineer, Pennsylvania Highway Commission, Harrisburg, Pa.; Discussion, A. W. Muir, Superintendent of Maintenance, New Jersey Highway Commission, Trenton, N. J.

### TRAFFIC

Thursday, Jan. 18, 2:30 p. m.—"Tourist Traffic as a Factor in Highway Development," illustrated, A. R. Hirst, State Highway Engineer of Wisconsin, Madison, Wis.; "Changes Needed in Motor Vehicle Legislation and License Fees," J. N. Mackall, Commissioner of Roads, Baltimore, Md.; Discussion, Leon C. Herrick, Director of Highways and Public Works, Columbus, O., and Harry Meixell, Jr., New York, National Automobile Chamber of Commerce.

Election of officers; business meeting.

### FINANCE AND MISCELLANEOUS

Friday, Jan. 19, 10 a. m.—"Have Large Expenditures Changed the Public Attitude Toward Highway Development?" S. E. Bradt, former Superintendent of Highways of Illinois.

# The Concrete Pipe Convention

Concrete pipe manufacturers will convene in Chicago at the Sherman Hotel, January 18, 19, 20, for the annual meeting of the American Concrete Pipe Association. Aside from the regular session for manufacturers, a special session of the convention is announced beginning at 2:00 o'clock Friday, January 19, to which practicing engineers and representatives of the various engineering journals are invited, because of a program of very general interest upon the subject of concrete pipe. Addresses at that session will be by Dean A. Marston, Iowa State College, Ames, Iowa, Langdon Pearce, Engineer, Sanitary District Chicago, A. M. Hirsh, president of the Lock Joint Pipe Co., Ampere, N. J., F. H. McCrory.

At other sessions the following special program features are announced:

Prof. D. A. Abrams and Stanton Walker, his associate in the Structural Materials Research Laboratory, Lewis Institute, Chicago, will preside at a special session, dealing with manufacturing problems, which will be held the morning of January 19. It will be devoted to the fabrication of good concrete. Ernest F. Bent, manager of the California Glazed Cement Pipe Co., Los Angeles, which has made very successful progress in concrete pipe manufacture in the far west, will offer suggestions on the manufacture and sale of concrete pipe.

G. G. Robinson of the Independent Concrete Pipe Company, Ltd., Toronto, will describe his company's experiences in developing the concrete pipe business in eastern Canada.

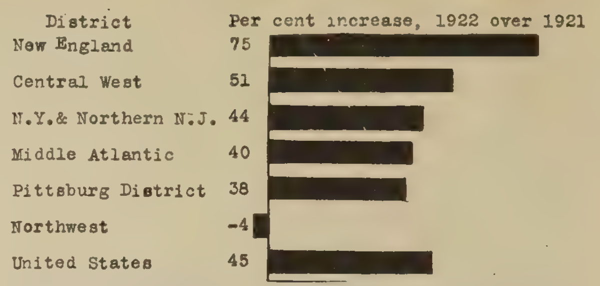
Roy H. Allison, consulting engineer Minnesota Concrete Drain Tile Manufacturers' Association, Mankato, Minnesota, will describe the cooperative efforts of manufacturers in Minnesota in overcoming prejudice against concrete tile in that state. In this connection, it is pointed out that up to September, 1922, the year's output was approximately 105,000 tons of tile for the drainage systems of Minnesota, of which 100,000 tons were in concrete. F. A. Swanson, vice president Mid-State Construction Company, Hastings, Nebraska, has something to say on concrete culvert pipe.

There will be a dinner entertainment and smoker at 6:30 o'clock January 19 for members of the Association and their friends.

# Building Activity

Contracts let in the 27 northeastern states during 1922 will probably total not less than three and one-third billions of dollars, or 42% more than last year. As these are supposed to be about three-quarters of all the contracts let in the country, the total for the entire United States will be not far from four and one-half billions of dollars.

The area referred to as the 27 northeastern states is the area for which contract statistics are collected by the F. W. Dodge Co.: North Dakota, South Dakota, Minnesota, Iowa, Missouri, Illinois, Indiana, Wisconsin, Michigan, Ohio, Kentucky, Tennessee, West Virginia, Pennsylvania, New York, Vermont, New Hampshire, Maine, Massachusetts, Rhode Island, Connecticut, New Jersey, Delaware, Maryland, Virginia, North Carolina, South Carolina. When it is considered that this area covers something like one-third of the country, but is estimated to include 75% of the contracts, we are impressed with the extent to which our population is concentrated in the northeastern part of the country.



PER CENT INCREASE IN CONTRACTS LET, BY DISTRICTS
First 11 months, 1922
as compared with 1921

The figures for contracts let in this territory for the first eleven months of 1922 show an increase over the corresponding figures for last year of 45%. This increase, however, is by no means uniformly distributed. It varies from 75% in New England to 38% in the Pittsburgh district, and an actual decrease of 4% in the northwest district. These figures are indicated in the diagram.—Courtesy *Index*, Associated General Contractors of America.

# New Publications

## Roads

*Portland Cement Concrete Roads*—By James T. Voshell, district engineer, and R. E. Toms, senior highway engineer, Bureau of Public Roads (Bulletin No. 1077, United States Dept. of Agriculture); 67 pages, 6 in. x 9 in.

Prepared and published "to supply reliable information on the subject of concrete pavements for the use of highway engineers and others interested." While the work is offered as describing "methods of construction believed to represent the best practice at this time" (October 21, 1922), it is pointed out that as experience and research are continually suggesting improvements, those who have charge of concrete road construction are urged to keep themselves informed of results obtained by others engaged in similar work and by laboratory experiments. The various chapters include: Materials, Proportioning, Quantities, Design, Construction, Organization and Equipment, Capital Required, Cost, Maintenance, Resurfacing, and an appendix tabulating quantities of materials for various mixes and costs.

## Coal Pockets

The economical storage and handling of coal in "Concrete Coal Pockets" is the subject of a new promotional pamphlet issued by the Portland Cement Association. It describes and illustrates such structures in use with comparative figures of cost in handling coal; states other advantages of the concrete bins, and presents construction details with capacity tables for different grades and kinds of coal and coke.

# New Features in Concrete Road Construction

By Charles Upham
North Carolina State Highway Engineer
Raleigh, N. C.

During the past season many details have been developed in the design and construction of concrete road surfaces. There has been very little change in the manufacture and quality of cement. Efforts to control the quality of cement are being made by the manufacturer, and it is seldom that engineers are obliged to condemn cement.

Engineers are coming to realize that the standard tests on which sands are now being accepted or rejected do not show the true value or quality of these sands in concrete. Certain sands which will satisfactorily pass present standard specification requirements, when mixed in concrete will show low strengths of concrete when compared with concrete made from sand of standard requirements. In other instances, sands which do not pass the present day sand requirements, when mixed in the concrete, show strengths oftentimes in excess of the standard sand requirements. Therefore it seems that a new specification for the testing of sand will undoubtedly be written some time in the near future, calling for the sand samples to be tested in concrete, and probably in a compression and transverse test, rather than in the present day tensile test method.

Recent experiments and research carried on by the North Carolina Highway Commission also point to the fact that it will be economy to call for a stricter gradation of large aggregates of concrete. It has been found that the gradation of the larger aggregate, while all other details remain equal, has caused the change in strength of the aggregate from 20% to 35%.

There seems to be a strong tendency in order to overcome weaknesses in construction to use hydrated lime in concrete road work, in order to facilitate the placing of the concrete. While in the laboratory, hydrated lime shows only average benefit, still under field conditions the average benefit is multiplied several times, and we find that the hydrated lime will assist in overcoming many construction weaknesses, which are often present in concrete construction. This has been determined after a period of careful experimenting ranging over several years.

During the past season much improvement has been made in the steel road forms used in the construction of concrete roads. At the present time it can be safely said that satisfactory road forms, for the first time, are now being manufactured and used by contractors generally. These forms are sufficiently heavy and rigid so that the handling of them does not cause the forms to become warped or bent. These forms are practically the first and chief requisite for the finishers to complete their roadway surface satisfactorily. Several finishing machines have been placed on the market during the past year. One recently tried out in North Carolina which gave very satisfactory results, consists of a heavy steel screed which strikes off the concrete to the proper crown and cross section. This screed is operated by power and leaves the road in exceptionally smooth condition, when the machine is operated on heavy forms.

Methods of handling road materials have changed somewhat during the past year. While the batch transfer and industrial railway method is popular in many localities, many contractors are using the batch transfer method and utilizing trucks instead of the industrial railway. In certain localities this is an exceptionally satisfactory method. Each truck carried from 1 to 6 batch boxes. In some instances the batch boxes are carried on trucks and trailers.

One exceptionally satisfactory method of handling materials of road construction seems to be the batch transfer method, where a combination of the industrial railroad and auto truck is used. The auto truck is used from the central proportioning plant or material supply to a point approximately one mile from the concrete mixer, where it is transferred to the industrial railway, which operates alongside the new pavement which is being placed and cured. After the pavement becomes hardened and of a certain age the auto trucks use the pavement over which to haul the batch boxes before the transfer to the industrial railway. This furnished a good road for the hauling of materials. The industrial railway is carried ahead with the concrete mixer as fast as the concrete pavement is opened for use.

Various methods of curing have been tried out, but the one which remains popular is the one where the concrete is immediately covered by wet burlap and on the succeeding day either covered with a layer of earth, which is kept soaked, or is cured by the ponding method, which consists of small dykes being thrown up on the edges of the pavement, and the area within covered with water.

Several sub-grade appliances for the shaping of the sub-grade have been in operation during the past year, and many of them have proven very satisfactory, depending upon the condition of the soil in which they are working. Possibly the most popular sub-grade device at the present time consists of a knife or plow which cuts the sub-grade to the proper depth. The plow is operated on the forms and can be pulled by a steam roller. In a few instances a power sub-grader has been used, but these have not become numerous.

Various types of construction or expansion joints are still in use, but the present tendency seems to do away with expansion joints. This detail seems to work out differently in the various states, but all these different methods seem to be working satisfactorily, provided the joint is so constructed that it is not a weak spot where corner breaks may commence. In most other instances, dowel bars are placed through the joint and extending into the adjacent slab. Circumferential or marginal reinforcement at the joints and corners is becoming universal.

During the past year the tendency seems to have been to increase the weight of the reinforcements in the concrete pavement, especially on the edges of the road, and to such a degree that some states are now using the marginal bar reinforcements in addition to the mesh reinforcements.

Much investigation has been carried on to ascertain the effect of various shaped cross sections. The one which seems to be most popular, and which probably will be used to the greatest extent during the coming year, is the so-called Arizona section. This consists of the depth of the edges of the pavement being increased, and this depth decreasing to a depth of 6 in. or 7 in. at a point 2 or 3 ft. from the edge. The remainder of the pavement remains the same depth, unless it is constructed in two sections, and then the depth at each edge of both sections is increased. A deviation of the Arizona section is the tentative North Carolina section, so designed as to allow contractors to utilize the 6-in. forms but still secure the practical depth of 9-in. on the road edges. This section consists of the 9-in. depth of road surface occurring at a point 6 in. from the outer edge. the edge of the pavement remains 6-in. in depth. This is to utilize the large number of 6-in. newly purchased forms now in use.

This pavement is designed to overcome the tendency for concrete pavement to commence breaking up at the corners or edges. Experiments seem to show that if the corners and edges of the concrete pavements could be heavily reinforced or the strength increased sufficiently to keep the pavement from breaking at these points, the remainder of the pavement will give sufficient support to carry the present day traffic.

The vast amount of money which will be spent in road surfaces in the next few years has created considerable experimenting and research. This work has brought out the fact that at the present time many of our methods and materials are exceptionally extravagant and expensive. If the great strides in experimenting and research are continued in the next few years, it is perfectly safe to prophesy that within five years roads will be constructed for 80% of their present cost, or if the same prices are paid, the quality of pavements or road surfaces will be bettered to the extent of at least 20%.

No radical changes in the construction of concrete pavements is looked for, but a change in the details of construction is expected, and it is this change of details which will improve the quality as well as reduce the expensive, and what appears to be extravagant, construction.

## New Miami Fordson Trailer

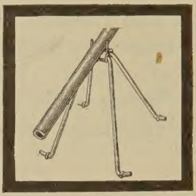
The constantly increasing use of the Fordson Tractor in commercial hauling and other industrial work has created a demand for special hauling equipment designed to be used with it. To meet this demand, the Miami Trailer Co., Troy, Ohio, has just announced a new special Miami Fordson trailer. It is of all steel construction, except wheels and tires. It has a rounded load capacity of 2 yds., with provision for mounting a separate flared top box of ½ yd. or 1 yd. extra capacity for transporting materials of a total load of 2½ tons, but of greater volume than 2 cu. yds. With ample factor of safety, the carrying capacity is 2½ tons. The body has a rear bottom dump door, so that the size of the opening may be controlled either to dump the entire load in one spot, or to spread the contents.

The turning radius is that of the Fordson Tractor. The unit can be backed into any position or can be turned around easily on the sub-base of a road. The trailer is especially offered for road and street contract work; for repairing streets and roads; for hauling and spreading crushed stone, gravel, cinders or dirt; for transporting concrete mix over sub-grades; for hauling brick; for hot asphalt; for building and excavating work; for constructing dams, levies and embankments; for coal deliveries at curbstone and manhole; for transporting refuse sand from foundries; for garbage and refuse disposal in cities.

While designed to be used with the Fordson tractor, the equipment is adapted for use with other tractors with a drawbar rating similar to the Fordson. It can also be used with 2½ and 3-ton high speed trucks, as the equipment is mounted on Timken roller bearings, and can be subjected successfully to the speed of the high speed truck.

## Screed Chair

The illustration shows a Kalman screed chair, offered as a means of securing correct thickness and uniform level for concrete floor slabs. Strong chairs, supporting ¾-in. pipe, are used as a thickness gauge, and as a screed or guide for the straight edge, with which the concrete surface is struck off. When shipped, chairs are collapsed, so take up small space. With the feet turned out, they are fastened down with nails or staples to the forms. After screeding the pipe is removed for re-use; the chairs remain in the concrete.



## Joint Filler to Match Road

Rodewite is a cement-colored plastic compound that can be melted readily in the usual type of roadmaker's stove and poured into the joints and cracks in concrete roads. It is then "tooled" to a smooth surface with a hot iron. It becomes stiff although plastic. It is offered to improve the appearance of concrete roads whose cracks are now filled with black material.

With Rodewite no dark streaks are visible. Being the color of Portland cement, it is difficult to tell where the expansion crack exists after it has been filled. Moreover, it has a high resistance to abrasion; it is said to be waterproof, and it does not disintegrate in the sun.

For a long time highway engineers have been seeking a composition that would have the desired qualities for filling the expansion cracks, and at the same time present an appearance as nearly uniform as possible with the road. State and Federal highway bureaus have been investigating the matter and the assistance of chemists has been enlisted. As a result, Rodewite has been evolved and is now being made on a commercial scale by the Capitol Rodewite Co., South Washington, Va. The U. S. Bureau of Public Roads is using this material in the construction of a three mile experimental highway in Virginia. Numerous State highway commissions have ordered trial lots.

*Special Road Builders and General Utility Type of Automatic Dump Body*—The Mandt Co., Keokuk, Iowa. A circular describing and illustrating the complete line of Mandt dump bodies, for various uses; among them a heavy duty automatic 1½ yd. and 2 yd. body for speed or for road builders. The descriptions also include a 1-yd. Ford body, operated from the seat and having an automatic opening end gate.

*A Hug Sub-grading Machine Ready for the New Nine-Inch Specifications*—Hug Co., Highland, Illinois. The sub-grading equipment has been changed to meet the new specifications of the Illinois State Highway Department, which require a thickness of 9 in. of concrete at the edge of the pavement, tapering to 6 in. thickness 2 ft. from the edge, and extending in a uniform 6-in. thickness throughout the rest of the slab. The new specification has only recently been adopted in Illinois, as a result of analysis of the Bates road tests.

# How many of these Questions can YOU answer?

For full information about the convention and American Concrete Institute activities address

HARVEY WHIPPLE, Secy.,
American Concrete Institute,
1807 East Grand Blvd.,
Detroit, Mich.

**Ask for information about reduced railway fare to Cincinnati meeting.**

How to make molds, place concrete and finish surfaces in ornamental concrete work? (An actual demonstration will be made)

Why do some of the biggest and most successful contractors place their concrete from buggies rather than through chutes? What are the relative advantages of the two methods of placing?

Why does the average contractor use a **batch** in preference to a **continuous** mixer?

How to make and lay concrete pipe for water pressure lines?

What methods have been found successful in making concrete floor finish set up quickly in cold weather?

How can laboratory tests which are now being made with regard to consistency of concrete be put into practical use?

When is feldspar a dangerous aggregate?

Is the use of pre-mixed aggregate now on the market and in common use in some cities to be encouraged or discouraged for concrete structures of small sections such as occur in building work? Is the use of pre-mixed aggregates economical? What are their other advantages and disadvantages?

Is it better to install cement fill and finish before or after plastering is done?

How was concrete cast and finished for Lorado Taft's large sculpture— "The Fountain of Time"?

Does the economy which the use of slag aggregate entails warrant its use in reinforced concrete buildings?

How may cinders be used most successfully for roof-fill to avoid expansion and displacement of parapet walls?

Is the value of integral waterproofings purely psychological in its effect on the contractor?

What are the causes of the corrosion of steel and the disintegration of concrete under special conditions of exposure? What are the remedies?

How can a satisfactory surface finish be given to concrete industrial buildings?

How can the costs involved in the manufacture of concrete block and concrete structural tile be analyzed?

Under what conditions is it more economical in lowering the cost of concrete block and building tile to make special mixtures of aggregates rather than use a natural supply?

Is it more economical to operate a products plant twelve months in the year, or eight months in the year?
(Actual figures will be presented.)

How can costs be cut in concrete products manufacture by selection and combination of aggregates?

When is it safe to use impure water in mixing concrete?

What changes must be made in our road-building standards to meet present-day traffic conditions?

What are the possibilities for standardization of quality and united action in the development of concrete roof tile?

Will concrete blocks resist fire exposure to such an extent as to warrant a better insurance rate?

How are concrete stadiums designed and built?

How to build water tanks by a new method?

## *These and many others make up the convention program*

## *Come to Cincinnati and get the answers!*

**Rarely if ever before has a program been developed to produce more practical, on-the-job, dollars and cents information than the offering to contractors, concrete products manufacturers and engineers, at the Convention of the American Concrete Institute at Cincinnati (Sinton Hotel) January 22, 23, 24, 25, 1923. Whether a member of the Institute or not, you are welcome to attend.**

## Trade Publications

A new circular, *The Hug Speed Truck,* gives a complete description and performance record of the Hug truck, The Hug Company, Highland, Ill., built for speed in the work of the road contractor. The manufacturers call attention to performance on several jobs. On the Powell-Gauen company job near Waterloo, Illinois, where the Hug plant layout was used, a hauling cost is reported as 6½c per ton mile. The length of job was 7.254 miles, maximum haul 3.9 miles, average haul 1.82 miles, number of trucks 12, square yards of pavement laid 76,600, tonnage haul 29,643, average tons per load 1.83, ton miles hauled 53,950, trips 15,937, truck miles traveled 58,010; 5,687 driver hours at 30c, 630 mechanic hours at 50c, 7,050 gallons gasoline at 18¾c, 226 gallons lubricating oil at 68c.

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*National Steel Fabric*—National Steel Fabric Co., Pittsburgh, Pa., a two-fold 8½ in. by 11 in. circular, describing a No. 14 gauge, cold drawn, galvanized, welded steel wire fabric, having a backing of heavy waterproof paper. The material is offered as a base and a reinforcement for stucco exteriors, partitions, ceilings, and for porch and bathroom floor construction. It is made in 2 in. x 2 in. and 2 in. x 4 in. mesh. Crimps in the fabric provide eyes through which wire ties secure the paper backing. The crimps provide self-furring. The circular describes and illustrates the several uses of the material.

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Hydro hoist users will be interested in *The Hydro Hoist and Dump Bodies Parts Price List No. 2,* just issued by The Heil Co., Milwaukee, Wis. It is very complete and comprehensive, size 8½ in. by 11 in., 76 pages and cover.

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## *Organizations*

**American Concrete Institute; Secretary, Harvey Whipple, 1807 East Grand Boulevard, Detroit. Convention, Cincinnati,** Ohio, January 22-25, 1923.

**American Concrete Pipe Association, M. W. Loving, Secretary, 111 West Washington St., Chicago.**
Convention January 18-20, Sherman Hotel, Chicago, Ill.

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American Engineering Standards Comm., Dr. P. G. Agnew, Secretary, 29 W. Thirty-ninth Street, New York City.

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Asso. General Contractors of America, G. W. Buchholz, Secretary, 1038 Munsey Bldg., Washington, D. C. Convention probably January 30 to February 2, 1923. Los Angeles, Cal.

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Associated Metal Lath Manufacturers, 123 W. Madison St., Chicago; Wharton Clay, Commissioner.

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Portland Cement Association; William M. Kinney, General Manager, 111 West Washington Street, Chicago.

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**Iowa Cement Stave Silo Association; H. E. Kilmer, Secretary, Oskaloosa, Ia.**

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**Mid-West Concrete Products Assn., Frank Whipperman, Secretary-Treasurer, 3045 Fowler Bldg., Omaha, Neb.**

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**National Crushed Stone Assn.; A. P. Sandles, Secretary, 405 Hartman Bldg., Columbus, Ohio.**

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**National Housing Assn.; Lawrence Veiller, Secretary and Director, 105 East 22nd St., N. Y. C.**

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**The National Lime Association; Mather Bldg., Washington, D. C.**

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National Sand and Gravel Producers' Association; T. R. Borrows, Acting Secretary, 903 Munsey Bldg., Washington, D. C.

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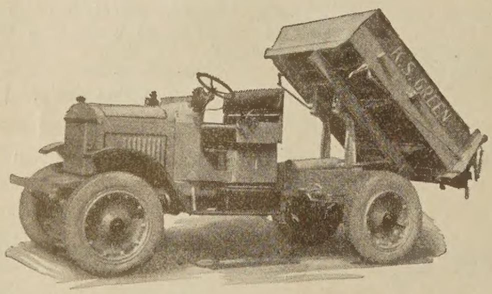
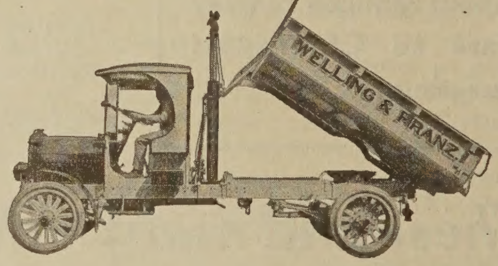
**The National Concrete Stave Silo Asociation; W. G. Kaiser, Secretary, 111 West Washington St., Chicago.**

**ST. PAUL HYDRAULIC HOISTS**



*MANY FEATURES OF PROVEN ADVANTAGE FOUND ONLY IN ST. PAUL HOISTS*



ST. PAUL UNDERBODY HOISTS
5″ adapted to trucks of a rated capacity of ¾ to 1½ tons. Price $220.00.
6″ adapted to trucks having a rated capacity of 3 tons or less. Price $340.00.
8″ adapted to trucks having a rated capacity of 3½ tons or more. Price $375.00.

ST. PAUL VERTICAL HOISTS
5″ adapted to trucks having a rated capacity of 3 tons or less. Lifting strength in excess of 6 tons. Price $320.00.
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Individually designed mountings for all principal makes of motor trucks. Power take-off drive included with all hoists for latest models of trucks. Simplicity of all mountings makes installation easy. Maximum strength at reduced weight; little chassis space required. *Superior in design, workmanship* and *material.*

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